1935

TECHNICAL BULLETIN No. 227 JANUARY, 1935

New York State Agricultural Experiment Station

Geneva, N. Y.

STUDIES ON APPLE SCAB AND SPRAY MATERIALS FOR ITS CONTROL IN THE HUDSON VALLEY

J. M. HAMILTON

PUBLISHED BY THE STATION
UNDER AUTHORITY OF CORNELL UNIVERSITY

ABSTRACT

Seasonal development records of the apple scab fungus (***Venturia inaequalis***) during the years of 1930 to 1934, inclusive, in the Hudson Valley indicate that ascospores may be discharged over a period extending at least from the middle of April (host in early delayed dormant stage) to the last week in June (terminal growth of host complete). The incidence of scab inoculum, frequency and duration of wetting periods, and temperature, particularly in the latter part of the season, are the essential factors in determining the first, major (usually occurring during May), and last primary infection periods, and consequently the value of any given individual spray. Commercially, the pink, calyx, 10-day, and codling moth (mid-June) sprays have been the most important.

Extensive tests have been made of the effectiveness and desirability of the more promising sprays containing lime-sulfur, wettable sulfurs and the like, sulfur dusts, and copper materials, and their use with arsenicals. Emphasis has been placed on adhesiveness, scab control, injury, finish of fruit, the residue problem, and the effect of sprays applied during bloom.

Spray materials used to control scab can be classified generally into those that are protective and eradicative, such as lime-sulfur and, to a lesser degree, dry lime-sulfur; and those that are merely protective, such as wettable sulfurs, sulfur dusts, and copper sprays. ***When timely applied*** wettable sulfurs have given satisfactory scab control, but when ***untimely applied*** serious scab has developed. More frequent application, as compared to lime-sulfur, would seem desirable. The most satisfactory results can only be obtained by a diversified program due to the fact that each material has its own merits and limitations. Choice of material depends on the incidence of scab, the relationship of the last infection period to the stage of host development at the time it is to be applied, weather, variety, time of year, and general orchard practice.

Adhesive studies indicate that wettable sulfurs and sulfur dusts may give less than, as much as, or more sulfur residue than lime-sulfur depending principally on the rates of application and the concentrations of the material used. The percentage of fine sulfur in a given material is obviously the major consideration in determining its effectiveness and the concentration at which it should be used. But thoroness or frequency of application, rainfall, and varietal, leaf, and fruit characteristics and rate of growth must be considered.

Texture of the apple cuticle and rate of growth are vital considerations in the arsenical residue problem. Amounts of arsenic retained on fruit varied with the different fungicides used. The material that leaves the least sulfur residue on the fruit may leave the greatest arsenical residue, and vice versa.

Altho laboratory tests indicate that sulfur and copper are toxic to apple pollen, the practice of spraying during bloom for scab control appears commercially feasible provided one (at most two) good pollination days have occurred prior to spraying.

TECHNICAL BULLETIN No. 227

STUDIES ON APPLE SCAB AND SPRAY MATERIALS FOR ITS CONTROL IN THE HUDSON VALLEY[1]

J. M. HAMILTON
Associate in Research (Plant Pathology)

INTRODUCTION

To obtain maximum results from the use of any spray material, knowledge must be had of the properties of the material and of the biological set-up under which it is expected to be effective. The prerequisites of an ideal fungicide in apple scab control are that it be preventive, eradicative, adhesive, toxic to the fungus but not to the host, and that it shall impart a good finish to the fruit. The results obtained from the use of an ideal fungicide would never be uniform, however, because of such variable factors as thoroness or rate of application, timeliness or frequency of application, environmental conditions such as rainfall, humidity, and temperature, seasonal variation of the fungus, growth and varietal differences of the host, orchard location, and orchard practices.

During the past three years studies have been continued in the Hudson Valley on the seasonal development of host, fungus, and disease.[2] Extensive tests have been made of the effectiveness and desirability of the more promising sprays containing lime-sulfur,

[1] The writer wishes to make special mention of S. B. Fenne and Karl H. Jarvis, the writer's temporary assistants in 1931–33 and 1934, respectively; of J. A. Evans and W. J. Clarke, Assistant County Agents; and of the fruit growers with whom the tests were carried on for assistance in the experiments reported here; and of L. M. Cooley of the Station Staff for aid in preparation of manuscript. Acknowledgment is also made of the cooperation of the following: Koppers Products Company, Pittsburgh, Pa.; Niagara Sprayer and Chemical Co., Inc., Middleport, N. Y.; National Sulphur Co., New York, N. Y.; Sherwin-Williams Co., Cleveland, Ohio; California Spray-Chemical Corporation, New York, N. Y.; Calcium Sulphide Corporation, Damascus, Va.; and the Ansul Chemical Company, Marinette, Wis.

[2] Investigations along similar lines for 1930 and 1931 are published in Bulletin No. 604 of this Station.

wettable sulfurs and the like, sulfur dusts, and copper materials, and their use with arsenicals. Emphasis has been placed on adhesiveness, scab control, injury, finish of fruit, and the residue problem. The effect of sprays applied during bloom has also received attention.

SEASONAL DEVELOPMENT OF SCAB

The seasonal development of the apple scab fungus (*Venturia inaequalis*) was followed by frequent microscopic examinations of the perithecia and with spore discharge tests made from representative samples of apple leaves collected thruout the Hudson Valley. The McIntosh variety was taken as a standard. The loose upper leaves were discarded in taking the leaf samples. The object was to collect at random those leaves that appeared ideally located to develop the perithecia and at the same time exposed enough to permit discharge into the orchard air. The samples were taken from orchards or trees that were badly scabbed the previous year.

The leaves were not cleared as is the usual practice. The immersion of the leaves for a second in boiling water is sufficient to fix the spores and preserve them in their natural state when the perithecia are crushed on a glass slide. The perithecia examined were those that were readily visible with a hand lens. Generally about 50 perithecia were picked at random from each sample of about 10 leaves. The trend of development was based on perithecia taken from leaves collected from the same orchards, usually about four, thruout the season.

The perithecia were tested for spore discharge by wetting the leaves for about 5 minutes, putting them on glass slides, absorbing the excess water with cheesecloth, and placing them over water in Petri dish bottoms to catch the spores for microscopic examination.

Records pertaining to temperature, humidity, rainfall, duration of wetting periods, rate of maturation, discharge of ascospores, infection and incubation periods, disease development on foliage and fruit, and host development and their relation to dates of spray applications for 1932, 1933, and 1934 are given in Figs. 1, 2, and 3 and in Tables 1 and 2. These records may be considered as generally applicable.

SEASON OF 1932

On April 14, 1932, ascospores were sufficiently mature to discharge from asci when put in water on a glass slide, but not directly from the perithecia *in situ* on the leaf. On April 26, approximately 35

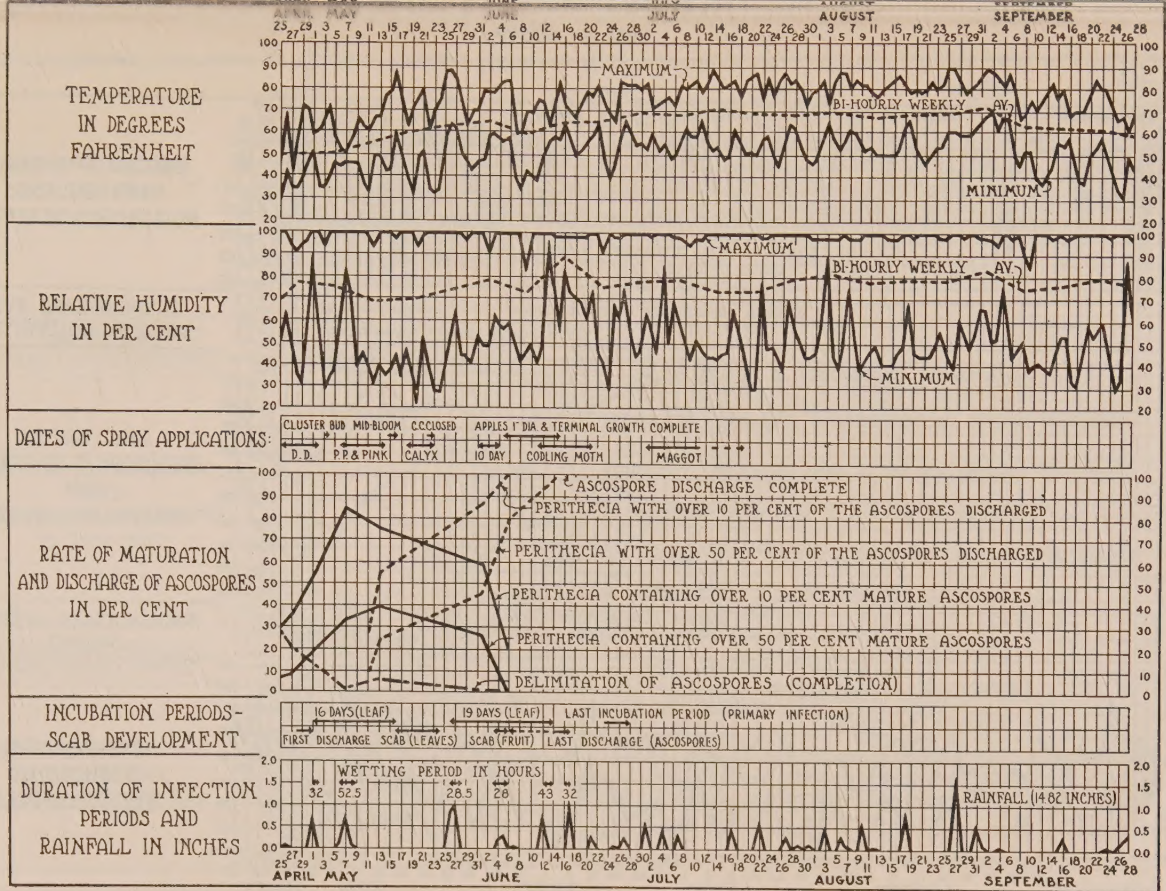

FIG. 1.—A GRAPHIC SUMMARY OF CERTAIN RECORDS RELATING TO THE SEVERITY AND CONTROL OF APPLE SCAB IN THE HUDSON VALLEY IN 1932.

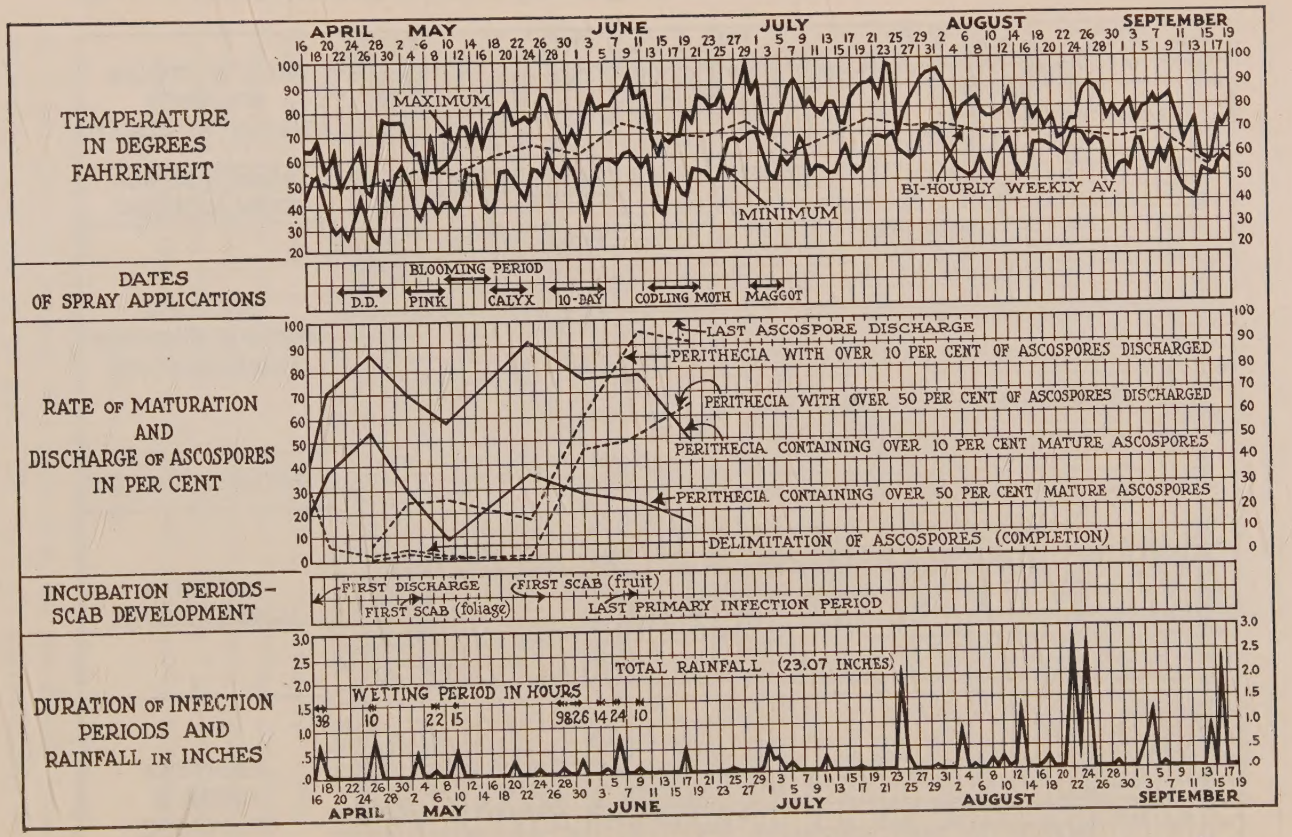

FIG. 2.—A GRAPHIC SUMMARY OF CERTAIN RECORDS RELATING TO THE SEVERITY AND CONTROL OF APPLE SCAB IN THE HUDSON VALLEY IN 1933.

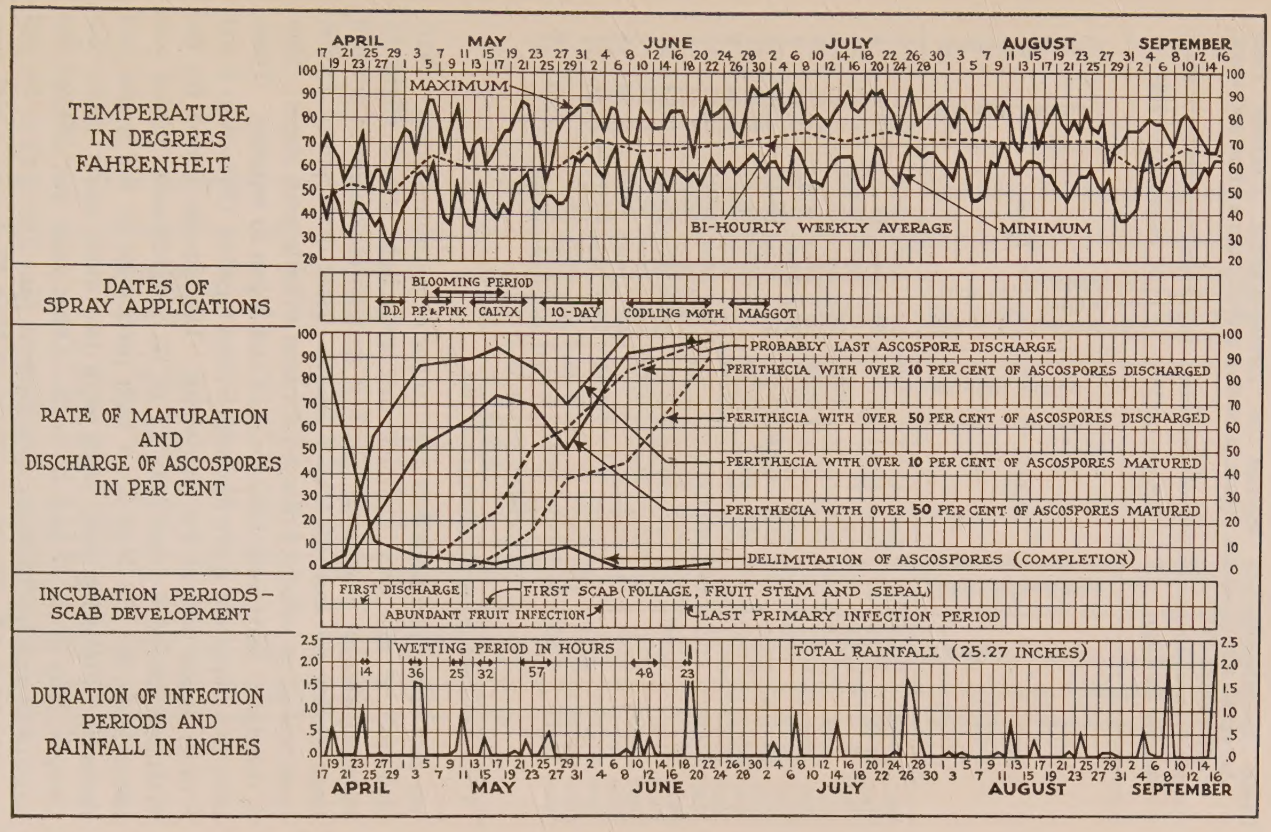

FIG. 3.—A GRAPHIC SUMMARY OF CERTAIN RECORDS RELATING TO THE SEVERITY AND CONTROL OF APPLE SCAB IN THE HUDSON VALLEY IN 1934.

TABLE 1.— APPROXIMATE RECORD OF ENVIRONMENTAL FACTORS THAT AFFECTED THE SEASONAL DEVELOPMENT OF APPLE SCAB AT POUGHKEEPSIE, N. Y., FROM 1932–34.

SEASON OF 1932			SEASON OF 1933			SEASON OF 1934		
Date	Rainfall, inches	Hours foliage wet	Date	Rainfall, inches	Hours foliage wet	Date	Rainfall, inches	Hours foliage wet
Apr. 25–26	0.05	20	Apr. 12–13	1.59	33	Apr. 19–20	0.60	19
May 1–2*	0.71	32	Apr. 16–18*	0.74	38	Apr. 23	0.04	2
May 6	0.13	4	Apr. 25	0.33	2	Apr. 24–25*	1.18	14
May 6–8	0.72	34	Apr. 26		8	Apr. 27	0.06	5
May 8–9	0.05	15	May 3	0.54	5	May 2–4	1.68	36
May 14	Trace	1	May 6	0.15	22	May 9–10	0.11	9
May 17	Trace	1	May 9–10	0.52	15	May 10–11	1.00	16
May 26	Trace	2	May 20	0.29	1	May 14–16	0.39	32
May 26–27	0.81	11	May 24	0.06	2	May 20	0.04	5
May 27–28	1.02	18	May 27	0.03	8	May 21–22	0.12	12
June 3	0.22	4	May 28		1	May 22–23	0.24	6
June 3–4		12	May 29		10	May 24–26	0.83	39
June 5–6	0.03	10	May 30	0.28	6	June 7	0.14	5
June 7		2	May 31		10	June 9–10	0.56	14
June 12–13	0.71	22	June 3	0.11	14	June 10–11	0.48	17
June 13–14		21	June 5	0.84	7	June 12–13		17
June 16–17	1.05	32	June 5–6		17	June 15	2.39	4
			June 9	0.04	10	June 18–19		23
			June 17	0.55	2			

* Date of first primary infection period for that year.

per cent of the perithecia had over 10 per cent mature spores. Petri dish tests at this time indicated that very light shoots might be expected with the next rain. The first spores were caught in orchard traps during the rain of May 1 and 2. Host development at this point was at an advanced delayed dormant to early pink stages. May 4, the cluster buds were fully exposed and began to separate. There were two important spore discharges close together (May 6 to 8 and 8 to 9) at the time of the pink spray. The blossom period for the McIntosh extended from May 12 to 17. Mid-blossom period was about May 16. By May 23, a high percentage of the spores had matured. Following this, there were two more major spore discharges, May 26 to 27 and 27 to 28. Other rains that affected the amount of primary infection were those of June 3 to 6, 12 to 14, and possibly 16 to 17. Perithecia examined May 30 showed a high per-

TABLE 2.— THE SEASONAL DEVELOPMENT OF THE APPLE SCAB FUNGUS AND OF ITS HOST IN RELATION TO INFECTION PERIODS IN THE HUDSON VALLEY, 1930–34.

YEAR *a*	PRIMARY INFECTION PERIODS	McINTOSH AT TIME OF FIRST INFECTION	BLOSSOM PERIOD FOR McINTOSH	ASCOSPORES MATURE APRIL 26 *b*	ASCOSPORE MATURITY PEAKS *c*	NUMBER OF RAINS	NUMBER OF INFECTION PERIODS *d*	NUMBER OF PREBLOOM INFECTION PERIODS
1930	May 14–June 11	Calyx.....	May 5–12	10	May 4–14.....	6	2– 6	0
1931	Apr. 23–June 17	Prepink.....	May 6–15	26	May 9–21.....	22	9–16	2 *e*
1932	May 1–June 17	Prepink.....	May 12–17	35	May 2–26.....	17	4–10	3 *f*
1933	Apr. 16–June 19	Delayed dormant..	May 9–17	88	Apr. 19–May 9, 23	18	2–8 *d*	3–5 *g*
1934	Apr. 24–June 19	Delayed dormant..	May 6–14	56	May 4–24.....	16	4–10	2 *h*

a The rainfall during the years 1930–34 from Apr. 17 to June 20 was 5.5, 10.21, 5.5, 4.98, and 12.09 inches, respectively, and from Apr. 17 to Sept. 15 it was 20, 22.41, 14.05, 23.54, and 25.27 inches, respectively.

b Percentage of perithecia with over 10 per cent mature spores.

c The major portion of the spores were matured during these periods. Immediately after these dates rains materially reduced the spore content of the perithecia. Commercially there were in general three scab periods for each year after these dates, the first one of which was a major one if not the heaviest spore discharge.

d The figures on the left refer to the number of major scab periods and those on the right to wetting periods 10 hours and over. In 1933 the wetting periods were short and scattered.

e The spore discharges were light, one after the prepink spray and the other at the time of the pink spray.

f Two of these were close together and important at time of pink spray and one was a light spore discharge immediately after the delayed dormant spray.

g Of these, two to three were important at the time of the pink spray. There was one light spore discharge before the delayed dormant spray and two at that time but with very short wetting periods.

h One of these was a light spore discharge at the time of prepink spray and the other a very light spotted and unimportant spore discharge before the delayed dormant spray.

centage of spore discharge and practically complete delimitation of spores, with paraphyses and much mycelial growth in evidence. A few spores ejected in tests June 17 were not viable under laboratory conditions. Terminal growth of the host was completed at this time.

Recurring "waves" of scab were observed May 16, May 19 to 24, June 3 to 6, and June 14 and 28 presumably as a result of the wetting periods of 32 hours, May 1 to 2; 53 hours, May 6 to 9; 29 hours, May 26 to 28; 26 hours, June 3 to 6; and 43 hours, June 12 to 14, respectively. Unsprayed trees showed 50 to 75 per cent fruit infected June 3 to 6.

The season of 1932 may be considered as average for the Hudson Valley, altho, generally speaking, the average orchard had more scab than in some years when it was more difficult to control. The number, intensity, and duration of infection periods varied markedly within even a few miles, particularly during the period May 6 to 9. The season was one in which scab was decidedly more prevalent on the fruit than on the foliage. This situation was brought about by rapid fruit growth but little foliage development between the calyx and 10-day sprays. Clean fruit resulted only in cases of a delayed calyx spray, an early 10-day spray, or an application immediately after the rain.

SEASON OF 1933

An examination of perithecia on April 3, 1933, showed about 25 per cent of the perithecia with between 10 and 50 per cent of the spores mature. The asci were mature enough by April 10 to give some discharge when removed to water on glass slides, but not directly from the perithecia in the leaves. Tests made in the laboratory on April 13 showed that the leaves with advanced perithecia would discharge viable spores and consequently there was danger from scab infection in the field from this date on. Vaselined glass slides showed that ascospores were discharged in the orchard with the rain of April 16 to 18. This light spore discharge came before the delayed dormant spray was applied. There were two additional light spore discharges April 25 and 26 at the time of the delayed dormant application but with very short wetting periods. About 88 per cent of the perithecia contained over 10 per cent mature spores at this time and the spores were all delimited. There were three major spore discharges May 3, 6, and 9 to 10 at the time of the pink spray. The last two at least resulted in the most important infection periods of

the season. The blossom period for the McIntosh extended from May 9 to 17. Mid-blossom period was about May 15 to 16. By May 9 it was certain that the first crop of perithecia had mostly discharged their spores and were well disintegrated. A new crop of smaller perithecia developed to form a second but minor peak to that of April 19 to May 9. On June 1 a few normal spores were still to be found in some of the perithecia. There were no primary infection periods after June 9, altho ascospores were found June 19.

Recurring "waves" of scab were found May 2 to 4, May 17 to 24, and June 12 and 24 presumably as a result of the infection periods of 38 hours, April 16 to 18; 22 hours, May 6, or 15 to 18 hours, May 9 to 10; 35 to 66 hours, May 27 to 31; and 38 hours, June 3 to 6, respectively. The wetting period of 15 to 18 hours on May 9 to 10 resulted in considerable fruit stem and sepal infection.

The season of 1933 was one in which apple scab was a minor problem. This fact was due to wetting periods of too short duration for infection to take place and the prolonged dry spell that existed during June, July, and part of August. The season was notable for the variability in distribution and duration of wetting periods within the limits of even a given locality. While there were several possible primary infection periods, it was apparent that only those at the time of the pink spray were important.

SEASON OF 1934

Examination of perithecia April 17, 1934, showed that asci were not sufficiently mature to discharge spores, but some of the spores were viable. On April 21 tests for spore discharge directly from leaves gave a very light shoot. The first spore discharge (very light and spotted) in the field occurred with the rain of April 24 to 25 which was two to three days before the delayed dormant spray. At this time about 56 per cent of the perithecia contained over 10 per cent mature spores. There was a light spore discharge which resulted in some scab May 2 to 4 at the time of the prepink or pink spray. Sudden bloom prevented the preblossom applications in most orchards. McIntosh began to bloom May 6. The calyx spray was recommended May 14. Petal fall was not complete on such varieties as Cortland, Delicious, Spy, Greening, and Rome Beauty until May 18 to 20. Considerable spraying was done during bloom because of the delayed petal fall resulting from winter injury. There were two spore discharges during bloom May 9 to 10 and 10 to 11 which gave

considerable fruit stem and sepal infection on May 16 to 17. Other infection periods occurred during the wetting periods of May 14 to 16, May 21 to 26, June 9 to 13 and possibly June 18 to 19. The major infection period was May 24 to 26 and resulted in considerable fruit infection on June 4 to 6. Unsprayed trees had about 100 per cent scabby fruit at this time. Perithecia began to disintegrate about May 28 and a new crop of the smaller perithecia was maturing spores. Good spore discharges were obtained June 12, altho paraphyses and mycelial growth were very prominent. Light spore discharge occurred from leaf samples June 22. Danger from primary infection was at a minimum after this date.

The season of 1934 was one in which scab control was most difficult despite the small carry-over of scab from 1933. As in 1932 and 1933, there was considerable variation in the distribution and duration of wetting periods thruout the Hudson Valley. The infection periods invariably preceded the spray applications. The poor timing resulted in considerable foliage infection and, unlike the preceding seasons, there was materially more secondary infection from the summer and fall rains.

DISCUSSION

In an attempt to summarize briefly the seasonal development of apple scab for 1932, 1933, and 1934 and to correlate it with that for 1930 and 1931, the first two years of this project, certain additional data are presented in Tables 2, 3, and 4. It is evident from these records that it would be difficult to forecast the date of spore maturation and discharge for any given season. The danger from primary infection in the field began about May 14, April 23, May 1, April 16, and April 24, respectively, for the five years. The percentages of perithecia with over 10 per cent mature spores on April 26 were 10, 26, 35, 88, and 56, respectively, for the years 1930 to 1934, inclusive.

From a study of the rainfall or wetting periods and the development of the perithecia at this time it is apparent that the date of first spore discharge each year is determined, in the main, by the number and extent of wetting periods. Other contributing factors are temperature, varietal differences, location of orchard, type of soil, and the time of leaf fall as affected by the amount of scab on the foliage. Neighboring orchards have been found to have a spread of from 15 to 45 per cent spores discharged by the middle of May. Spores may

be mature long before the perithecia are in a condition to permit discharge. This condition generally prevailed in the years 1930 and 1932. In other words, if there had been sufficient wetting periods, it would have been possible to have had primary infection earlier in those years. Such a condition tends to shorten the period of major spore discharges. It seems an assured fact that primary infection periods in the Hudson Valley are practically over by or shortly after mid-June.

It would seem from these records that the preblossom and the postblossom sprays may be equally valuable. There is no assurance that the severe infection periods are going to occur at the same time in a given year for everyone even in the same locality. While records show that, in general, the main spore discharges in the field occur close to the time of the spore peaks, it does not follow that these are necessarily the most important from the standpoint of actual control. The value of a given individual spray is affected by the relationship of the time of the infection period and the stage of host development at that time to its date of application.

During the past five seasons the pink spray has been the first commercially important spray each year, however it is evident from the seasonal development data that some scab infection could have taken place at delayed dormant period had sufficient wetting occurred. It is questionable whether or not this would be so in orchards where scab is under good control or where the varieties are resistant. An average of two sprays before bloom, one a late delayed dormant or early closed cluster and the other varying from the time the clusters are separating to full pink, have given good results so far as preblossom sprays are concerned in experimental orchards. The pink spray has generally been applied in an early stage. The experimental blocks have had, in general, a heavy incidence of inoculum to give maximum tests for scab control. For scab control alone, one spray, the pink, should be sufficient on resistant varieties or where scab is of minor importance.

The seasonal development of scab records indicate that the month of May takes in the major portion of the severe primary infection periods, but that commercially each spray up to and including the codling moth spray may be of major importance. The calyx spray was most important in 1930; the pink, 10-day, and codling moth sprays in 1931; the pink, calyx or 10-day, and codling moth sprays

in 1932; the pink spray in 1933; and the prepink or pink, calyx, 10-day, and codling moth spray in 1934. The omission spray records (Table 3) show that the importance of these sprays is not always

TABLE 3.— THE EFFECT OF OMITTING APPLICATIONS IN THE LIME-SULFUR SPRAY PROGRAM ON MCINTOSH, IN THE HUDSON VALLEY, 1930–34, INCLUSIVE.

TREATMENT*	TOTAL PERCENTAGE SCABBED FRUITS				
	1930	1931	1932	1933	1934
Untreated	80.2	61.2	99.8	66.8	83.3
L–S, 1–40†	2.6	1.0	6.0	0.0	5.5
L–S (delayed dormant omitted)	‡	‡	1.4	0.0	4.5
L–S (prepink omitted)	3.1	‡	2.5	‡	3.5
L–S (pink omitted)	0.5	**14.2**	1.3	**17.3**	3.0
L–S (calyx omitted)	**40.6**	**9.5**	6.2	0.1	3.9
L–S (10-day omitted)	2.9	**17.0**	2.1	0.0	2.9
L–S (codling moth omitted)	.....	**10.4**	**16.3**	0.0	.....

* Arsenate of lead 3–100 was used with the lime-sulfur in all applications.
† Lime-sulfur 1–50 was applied in 1934.
‡ Sprays were not applied.

apparent. This is due, of course, to the relation of the spray applications to the infection periods and the fact that lime-sulfur exhibits fungicidal value after infection periods and burns out mature scab lesions. The importance of any given spray in any given year does not necessarily apply thruout the Hudson Valley. It may be the pink spray in one area and the codling moth spray in another. The lower part of the Valley is considerably earlier than the upper part, and in general, the farther from the river, the later the scab development. The value of any single treatment of the spray schedule is almost entirely dependent on the frequency and duration of wetting periods. The importance of the later sprays apparently depends on the early maturity of the spores and the temperature and rainfall after petal fall. Slow maturity in the spring and discharge before too high a percentage are mature tend to lengthen the primary infection period. Cool weather favors development until well on into June, whereas hot weather prevents the maturation of small perithecia, particularly those in surface leaves. There were practically two ascospore-production peaks in 1933 and 1934, while in the other three years the only apparent peaks were those in perithecia that were macroscopic in early season.

The chance importance of any spray in a given year is dependent on the amount of scab the previous year and the number and dura-

TABLE 4.— A COMPARATIVE RECORD OF THE AMOUNT OF APPLE SCAB ON UNSPRAYED McINTOSH AT HARVEST IN THE HUDSON VALLEY, 1930–34 (R. SMITH).

YEAR	NO. OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
1930.....	1	525	3.8	2.5	0.4	**6.7**
1931.....	1	831	27.4	20.1	13.7	**61.2**
1932.....	1	4,937	1.3	1.7	96.6	**99.6**
1933.....	1	2,574	3.3	1.8	1.7	**6.8**
1934.....	1	2,203	24.1	23.6	35.6	**83.3**

tion of wetting periods for the current year (Table 4). Unsprayed McIntosh that picked 6.7 per cent scabby fruit in 1930, a non-scabby year, picked 61.2 per cent scabby fruit in 1931, a season of many wetting periods. The slow maturation of spores in 1930 due to lack of wetting periods prepared the way for one major discharge at the time of the calyx spray at which time practically all the spores were shot. The spore discharge in 1931 began with fewer spores mature, and hence with the aid of many wetting periods, the primary infections were numerous and continued over a longer period of time. There was a heavy carry over of scab to 1932. While the season of 1932 was only an average year, the percentage of scab increased from 61.2 to 99.6 with a higher percentage of bad scabby apples.

Altho there were the average number of spore discharges in 1933, they were not of sufficient duration to cause scab infection and the percentage of scab dropped from 99.6 to 6.8 as it was in 1930. The season of 1934 was almost as satisfactory as 1931 for scab development and the amount of scab on the unsprayed trees increased from 6.8 per cent to 83.3 per cent, or about the same increase as took place in 1931. There were 6, 22, 17, 18, and 16 rains with 2, 9, 4, 2, and 4 major scab periods during the primary infection periods for the years 1930 to 1934, inclusive, respectively.

ORCHARD TRIALS OF SPRAY AND DUST MATERIALS

METHODS

SELECTION OF PLATS

Experimental plats were located for the most part in situations where apple scab had been severe in previous seasons. An attempt was made to select trees in good bearing and as uniform as possible in size, condition, and surroundings. The size and arrangement of

plats was such as to minimize possible errors that might arise due to drifting spray or unequal scab conditions.

SPRAY MATERIALS

Lime-sulfur.—The standard, commercial liquid concentrate testing 32° Baume.

Dry lime-sulfur.—A dry form of lime-sulfur which contains sugar as a stabilizer. Prepared by the Sherwin-Williams Co., Cleveland, Ohio.

Dry mix.—A mechanical mixture of sulfur, hydrated lime, and some wetting agent, such as casein spreader or goulac. A high grade 300-mesh sulfur and a high calcium hydrated spray lime were used. Unless otherwise stated, the several dry mix formulas tested were prepared by means of a mechanical mixer previous to use.

Koppers flotation sulfur paste.—This material comprises a blend of three types of flotation sulfur known as thylox, ferrox, and gray flotation. It contains about 40 per cent sulfur and is prepared by the Koppers Products Company, Pittsburgh, Pa., as a by-product in the purification of manufactured gas.

Koppers dry wettable flotation sulfur.—A dried and pulverized flotation sulfur paste as described above. Contains about 85 per cent sulfur.

Blended Koppers flotation sulfur dust.—Composed of 25 parts of Koppers flotation sulfur dust and 75 parts of 300-mesh ground roll sulfur dust. The Koppers sulfur dust is made of ferrox and thylox flotation sulfur.

Camden flotation sulfur paste.—Composed of blended ferrox and gray types of flotation sulfur. Guaranteed to contain 35 per cent sulfur. Prepared by Camden Coke Plant, Camden, N. J.

Kolofog.—Technically known as bentonite-sulfur, which is the finely divided super-active ingredient of the Niagara Kolo Dusts. Prepared by fusing sulfur into bentonite with which it has been previously blended. Contains from 30 to 40 per cent sulfur. Manufactured by Niagara Sprayer and Chemical Co., Inc., Middleport, N. Y.

Kolodust.—A proprietary bentonite-sulfur dust prepared by the Niagara Sprayer Chemical Co., Inc., and guaranteed to contain not less than 90 per cent sulfur. It is a mixture of bentonite-sulfur and 300-mesh ground roll sulfur.

Super-Sulfodust.—A 300-mesh ground roll sulfur guaranteed to contain not less than 92 per cent sulfur. Prepared by the Niagara Sprayer and Chemical Co., Inc.

Magnetic-Spray.—A wettable sulfur containing about 99 per cent sulfur prepared by the National Sulphur Company, Inc., New York, N. Y.

Magnetic-Dust.—A proprietary 300-mesh processed distilled dusting sulfur 99.8 per cent pure, prepared by the National Sulphur Company, Inc., New York, N. Y.

Cal-Mo-Sul.—Trade name for calcium monosulfide. Prepared by Calcium Sulphide Corporation, Damascus, Va.

Ansul colloidal sulfur paste.—A chemically made colloidal sulfur paste with a 10 to 20 per cent water content manufactured by the Ansul Chemical Company, Marinette, Wis.

Coposil.—A proprietary copper fungicide, copper ammonium silicate, designed to overcome certain inherent disadvantages of bordeaux and for use in combination with insecticidal oils. Prepared by the California Spray-Chemical Corporation, New York, N. Y.

Precipto.—A sulfonated oil used to precipitate the free sulfur from liquid lime-sulfur. Manufactured by Central Chemical Company, Inc., Baltimore, Md.

Lime.—A high grade hydrated calcium lime, especially ground for spraying, was used in all cases.

APPLICATION OF SPRAYS AND DUSTS

The spray materials were prepared in the tank according to standard recommendations. Spray guns were used in the majority of the experiments. The trees were covered as thoroly and evenly as possible and at the same time drenching was avoided.

The dust applications were applied thoroly to both sides of the trees. The treatments were usually made in the morning before the dew dried.

Every effort was made to put the materials tested on a comparable basis.

SAMPLING AND GRADING OF FRUIT

The trees upon which counts were to be made were selected as representative in regard to condition, quantity of fruit, and location for scab.

Scabbed fruit was divided into three classes, *viz.*, slight, medium, and bad. Slight scab included those fruits bearing scab spots affecting a total area up to ¼ inch in the aggregate, medium scab up to ¾ inch, and bad scab more than ¾ inch. This classification is based on the New York State grading law.

SCAB CONTROL AND HOST INJURY

Successful spraying is based on three considerations, *viz.*, correct timing or frequency of application, thoroness of application, and the use of proper materials. Spray materials on the market can be

roughly classified as those that are both protective and eradicative, such as lime-sulfur and, to a lesser degree, dry lime-sulfur; and those that are generally merely protective, such as wettable sulfurs, sulfur dusts, and copper sprays. Data pertaining to the adhesive qualities of sulfur sprays and dusts are presented on pages 29 to 43.

LIQUID LIME-SULFUR

Lime-sulfur 1-40 and lime-sulfur 1-60 have given practically the same degree of scab control in numerous tests (Tables 5 and 6). The adhesive studies indicated that lime-sulfur 1-40 gave about 40 per cent more sulfur deposit than lime-sulfur 1-60 until 2 inches or more of rain had fallen (Fig. 4). Records indicate that 2 to 3 inches of rain would be about the maximum to be expected between sprays. Generally, an application of either strength of lime-sulfur would be ineffective due to new growth before the factor of amount of protection became apparent. It is possible that if lime-sulfur 1-40 were applied in the last spray, about the first of July, to an apple block with severe foliage infection that the fruit would have maximum protection against summer and fall infection.

A complete lime-sulfur program under average conditions in the Hudson Valley generally causes rather severe injury, particularly to the foliage. A reduction in the number of fruit blossoms, in the set of fruit, and in fruit size has been observed. Serious injury, apart from varietal susceptibility, is usually correlated with low vigor of the trees or poor orchard practices, spraying technic or environmental factors. It has been observed that lime-sulfur frequently causes severe injury by aggravating frost injury early in the season. Correctives, such as excess lime, aluminum sulfate, Kayso, iron sulfate, and Precipto, are ineffective or have other drawbacks. The use of hydrated lime at the rate of 1 pound for each pound of arsenate of lead to be put in the tank before the lead is apparently a good practice to follow. Diversification in the selection, use, and application of materials together with vigorous, well-pruned trees is obviously the most satisfactory spray practice to follow.

LIQUID LIME-SULFUR WITH CALCIUM ARSENATE

Combinations of lime-sulfur and calcium arsenate produced serious injury in 1933. Under conditions in the Hudson Valley this combination should be avoided except perhaps on vigorous trees of hardy varieties, such as McIntosh. The most rigorous care should be exer-

TABLE 5.— THE COMPARATIVE EFFECTIVENESS OF WETTABLE SULFURS AND SPRAYS CONTAINING LIME-SULFUR WHEN TIMELY APPLIED IN THE HUDSON VALLEY IN 1931, 1932, AND 1933.

TREATMENT *a*	NO. OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
Ser. 1*b* 1931, McIntosh (Average of 6 Orchards)						
Untreated	16	6,114	15.6	14.6	43.0	**73.2**
Lime-sulfur 1–40	18	16,641	0.7	0.7	0.6	**2.0**
Lime-sulfur 1–60	20	20,354	1.6	1.0	0.5	**3.1**
Ser. 2*b* 1931, McIntosh (Average of 4 Orchards)						
Untreated	14	3,849	11.4	11.1	50.7	**73.2**
Lime-sulfur 1–60	18	15,448	1.4	0.9	0.5	**2.8**
Koppers paste 5–50	19	18,160	1.2	0.8	0.3	**2.3**
Kolofog 4–50	19	16,157	2.6	1.8	1.1	**5.5**
Ser. 3*c* 1932, McIntosh (L. Craft)						
Untreated	4	1,924	17.5	4.8	33.6	**55.9**
Lime-sulfur 1–40	2	4,848	0.4	0.4	0.4	**1.2**
Dry mix 12–8–½	2	6,257	1.3	0.7	1.7	**3.7**
Koppers paste 5–50	2	7,466	0.5	0.4	0.5	**1.4**
Koppers dry 3–50	2	5,637	0.2	0.2	0.1	**0.5**
Kolofog 4–50	2	4,853	0.3	0.5	0.4	**1.2**
Ansul sulfur 3–100	2	3,421	0.1	0.1	0.2	**0.4**
Ser. 4*d* 1932, McIntosh (F. Battenfeld)						
Untreated	2	2,666	18.2	5.6	57.1	**80.9**
Lime-sulfur 1–40	4	5,067	0.0	0.0	0.1	**0.1**
Lime-sulfur 1–60	4	5,807	0.2	0.1	0.1	**0.4**
Dry mix 12–8–½	4	4,686	0.5	0.0	0.1	**0.6**
Koppers dry 3–50	4	5,629	0.2	0.1	0.1	**0.4**
Kolofog 4–50	4	5,955	2.0	0.6	0.3	**2.9**
Ser. 5*e* 1932, McIntosh (C. Miller)						
Untreated	2	5,511	12.6	11.3	59.7	**83.6**
Lime-sulfur 1–60	2	6,996	0.0	0.0	0.0	**0.0**
Dry mix 12–8–½	2	8,206	0.1	0.1	0.0	**0.2**
Dry mix 8–8–½	2	8,293	0.1	0.0	0.0	**0.1**
Kolofog 4–50	2	8,706	0.2	0.1	0.2	**0.5**
Koppers dry 3–50	9	4,515	0.0	0.1	0.0	**0.1**

a Abbreviations as follows: Koppers paste = Koppers flotation sulfur paste; Koppers dry = Koppers flotation dry wettable sulfur; Ansul sulfur = Ansul colloidal sulfur paste. Bordo = bordeaux mixture. The concentrations are expressed as so many pounds in the given number of gallons of water. Where three figures are present in the formulae the second refers to pounds lime. Dry mix (sulfur, lime and kayso or goulac) is always rated per 100 gallons. Commercial powdered arsenate of lead 3–100 was used in all of the sprays except as otherwise noted. Lime 3–100 was added to the lime-sulfur solution in every instance before the arsenate of lead. Lime, unless otherwise stated, was added to Kolofog in the latter sprays as recommended by the manufacturer.

b Data taken from Table 3, Bulletin No. 604, of this Station.

c Lime-sulfur 1–40 was applied to all blocks in the pre-blossom sprays, Apr. 30 and May 6. Four applications of the above treatments were made after bloom, May 20 and 21, June 14, and July 6. Last application was made only for adhesive studies.

d Lime-sulfur 1–40 was applied to all blocks in the pre-blossom sprays, Apr. 30 and May 6 and 9. Three applications of the above treatments were made after bloom, May 21 and June 1 and 14. Arsenate of lead and lime, each 3–100, were used alone in the last or first maggot spray, July 6.

e Oxo-bordo oil was applied in the delayed dormant, May 2, to all the blocks. Lime-sulfur 1–60 was used in the prepink, May 7. The wettable sulfur program began with the pink spray. Four applications of the above treatments were made May 14 and 23, and June 2 and 15. Arsenate of lead 3–100 was used alone in the last or first maggot spray, July 11.

TABLE 5.— *Concluded.*

TREATMENT	NO. OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
Ser. 6*f* 1932, McIntosh (S. Hubbard)						
Untreated	4	5,148	17.7	8.9	38.7	**65.3**
Lime-sulfur 1–60	3	9,868	0.3	0.1	0.1	**0.5**
Dry lime-sulfur 3–5–50	3	10,941	0.3	0.1	0.1	**0.5**
Dry mix 16–8–½	3	10,588	0.3	0.1	0.1	**0.5**
Dry mix 12–8–½	3	6,341	0.4	0.2	0.1	**0.7**
Dry mix 8–8–½	3	8,666	0.8	0.2	0.2	**1.2**
Ser 7*g* 1933, Red Delicious (J. Warner)						
Untreated	4	2,568	31.1	9.1	20.5	**60.7**
Lime-sulfur 1–60	8	1,260	0.0	0.0	0.0	**0.0**
Magnetic-Spray 6–100	4	1,967	0.2	0.1	0.0	**0.3**
Koppers dry 5–100	5	2,146	0.1	0.0	0.1	**0.2**
Kolofog 6–100	4	2,852	0.9	0.1	0.1	**1.1**
Dry mix 10–3–1	5	1,825	0.4	0.4	0.1	**0.9**
Ser. 8*h* 1933, Newtown (Palmer Hart)						
Untreated	1	2,191	35.7	16.7	22.9	**75.3**
Bordo 3–6–100	2	2,817	0.0	0.0	0.0	**0.0**
Bordo and Cal-Mo-Sul *i*	2	3,498	0.0	0.0	0.0	**0.0**
Cal-Mo-Sul 25–6–200	2	3,428	0.0	0.0	0.0	**0.0**
Coposil 3–6–100	2	2,158	0.0	0.0	0.0	**0.0**

f Bordo-oil emulsion was used in the delayed dormant, Apr. 28, and lime-sulfur 1–40 in the pink, May 6. Four applications of the above treatments were made after bloom, May 19 and 27, June 11, and July 5. Last application was applied only for adhesive studies.

g Lime-sulfur 1–60 was applied to all blocks in the delayed dormant, Apr. 26. Four applications of the above treatments were made, one in the pink, May 3, and three after bloom, May 22 and June 3 and 17. Calcium arsenate and lime, each 3–100, were used thruout. No lime was added to the dry mix. Goulac replaced Kayso in the dry mix.

h Lime-sulfur 1–60 was applied in the delayed dormant, Apr. 29. Four applications of the above treatments were applied, one in the pink, May 5, and three after bloom, May 22 and June 3 and 19. Calcium arsenate 3–100 was used in all sprays.

i Bordo 2–6–100 and Cal-Mo-Sul 6–100 were used.

cised in its application. Arsenical injury abounds wherever the foliage is injured in any way whether it be gun injury, fungous lesions, insect wounds, or wind whipping. A number of correctives, such as lime 6-100, iron sulfate 11-200, aluminum sulfate 5-100, have been used with lime-sulfur 1-60, and Cal-Mo-Sul 6-100 with lime-sulfur 1-100 with varying success. Goulac was used in all the combinations. The tests were made on Baldwin. The aluminum sulfate was perhaps the best corrective, but the foliage did not appear quite natural and there was some dropping of yellow leaves. Cal-Mo-Sul seemed to reduce the arsenical or lime-sulfur injury more than lime.

The iron sulfate treatment gave the most luxuriant foliage. However, the fruit did not size up. The apples from the treated block averaged 194 to the bushel crate, while the average from the blocks

TABLE 6.— THE COMPARATIVE EFFECTIVENESS OF WETTABLE SULFURS AND SPRAYS CONTAINING LIME-SULFUR WHEN NOT TIMELY APPLIED IN THE HUDSON VALLEY IN 1931, 1932, AND 1934.

TREATMENT *a*	NO. OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
Ser 1*b* 1931, McIntosh (S. Hubbard)						
Untreated	2	1,065	7.4	17.4	69.3	**94.1**
Lime-sulfur 1–50	2	2,885	1.7	1.5	0.7	**3.9**
Dry lime-sulfur 3–10–100	2	2,356	3.5	2.9	2.2	**8.6**
Kolofog 4–50	3	4,964	9.7	8.3	5.0	**23.0**
Ser. 2*c* 1931, McIntosh (H. Gage)						
Untreated	2	1,176	3.1	7.2	79.6	**89.9**
Lime-sulfur 1–60	2	3,261	0.8	0.4	0.4	**1.6**
Dry lime-sulfur 3–10–100	2	6,014	4.6	5.6	2.9	**13.1**
Dry mix 16–8–1	2	3,503	6.4	8.8	5.9	**21.1**
Dry mix 12–8–1	2	2,297	8.5	7.1	5.7	**21.3**
Ser. 3*df* 1932, Baldwin (W. Clarke)						
Untreated	2	7,265	24.2	10.4	27.0	**61.6**
Lime-sulfur 1–40	2	7,698	0.6	0.1	0.1	**0.8**
Dry lime-sulfur 3–5–50	2	9,921	5.5	1.1	0.9	**7.5**
Dry mix 12–8–½	3	15,659	7.7	1.9	2.3	**11.9**
Koppers dry 3–50	2	6,910	10.6	1.9	1.4	**13.9**
Kolofog 4–50	2	9,174	9.6	1.8	2.0	**13.4**
Ser. 4*ef* 1932, Winesap (L. Clark)						
Untreated	1	1,719	5.2	0.9	93.4	**99.5**
Lime-sulfur 1–60	4	7,269	1.1	0.8	1.2	**3.1**
Dry lime-sulfur 3–5–50	4	8,896	2.5	1.6	2.4	**6.5**
Koppers paste 5–50	3	8,978	4.3	1.9	3.6	**9.8**
Kolofog 4–50	3	6,723	4.4	1.1	2.6	**8.1**

a Abbreviations as follows: Koppers dry = Koppers flotation dry wettable sulfur; Koppers paste = Koppers flotation sulfur paste; Camden paste = Camden flotation sulfur paste. Commercial powdered arsenate of lead 3–100 was used in all of the sprays. Lime 3–100 was added to the lime-sulfur solution in every instance before the arsenate of lead. Lime, except as otherwise noted, was added to Kolofog in the latter sprays as recommended by the manufacturer.

b The 10-day spray was applied May 26. Three to four leaves were unprotected June 7. A total infection period of 92 hours took place June 7 to 12. One wetting period alone was 57 hours. The sprays were applied June 13. Dry lime-sulfur was used 6–10–100 up to and including the 10-day spray and reduced to 3–10–100 in the next two sprays, the codling moth and maggot. The whole block received the dry lime-sulfur in the maggot, July 3. (See Table 3, Bulletin No. 604 of this Station.)

c The same as *b*, except that the 10-day spray was applied May 29 and the following sprays June 15 and 16 and July 1. Lime-sulfur 1–40 was used on the dry mix rows up to and including the calyx. Lime-sulfur 1–60 and dry lime-sulfur, as noted above, were applied thruout on their respective blocks (Table 3, Bulletin No. 604 of this Station.)

d Bordo-oil emulsion was used in the delayed dormant Apr. 25. Lime-sulfur 1–50 was used on all blocks in the pink spray May 9. Three applications of the above treatments were made May 21 and June 3 and 21. Lime-arsenate of lead dust 85–15 was applied to all blocks in the last or first maggot application, July 19.

e Lime-sulfur 1–60 was applied to all blocks in the delayed dormant, May 2. There were four applications of the above treatments; one before bloom, May 9, and three after, May 23 and June 4 and 18.

f The calyx spray was applied to series 3 and 4, May 21 and 23, respectively. The scab came with the infection period of 29 hours May 26 to 28. The codling moth sprays were applied June 3 and 4, respectively.

TABLE 6.— *Concluded.*

TREATMENT	NO OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
Ser. 5*g* 1934, McIntosh (Gerow Schoonmaker)						
Untreated	5	1,941	3.7	4.9	89.0	**97.6**
Lime-sulfur 1–60	4	6,073	0.9	0.2	0.3	**1.4**
Dry lime-sulfur 3–5–50	3	4,504	7.1	1.2	0.6	**8.9**
Magnetic-Spray 6–100	3	7,784	0.9	0.8	1.3	**3.0**
Sulfrox 6–100	3	7,397	1.2	1.4	1.5	**4.1**
Koppers dry 5–100	3	7,719	0.8	0.8	0.8	**2.4**
Kolofog 6–100	3	10,140	2.0	2.0	3.1	**7.1**
Kolofog 6–8–100	3	7,114	15.4	3.4	5.2	**24.0**
Ser. 6*h* 1934, McIntosh (Mynard Van de Bogart)						
Untreated	4	1,089	0.0	0.0	100.0	**100.0**
Lime-sulfur 1–60	12	1,989	0.7	0.6	0.7	**2.0**
Lime-sulfur and Precipto	9	2,285	0.7	0.9	1.3	**2.9**
Koppers dry 5–100	11	6,803	1.7	0.9	0.8	**3.4**
Kolofog 6–8–100	8	4,705	2.7	2.3	2.3	**7.3**
Coposil 3–100	10	4,571	2.8	1.6	1.5	**5.9**
Ser. 7*i* 1934, Rome Beauty (J. Warner)						
Untreated	2	1,279	5.1	9.6	83.8	**98.5**
Lime-sulfur 1–60	17	5,323	0.2	0.4	0.5	**1.1**
Camden paste 8–100	14	5,270	0.4	0.7	1.1	**2.2**
Koppers dry 5–100	13	7,869	1.1	2.6	2.6	**6.3**
Koppers dry 3–100	17	8,609	1.7	4.0	3.0	**8.7**
Kolofog 5–100	12	4,962	1.8	4.1	3.5	**9.4**
Kolofog 3–100	15	6,964	4.7	6.7	6.6	**18.0**

g Lime-sulfur 1–50 was used in the delayed dormant and prepink sprays, Apr. 26 and May 4. Five applications of the above treatments were made, except that arsenate of lead and lime, each 3–100, were applied on the lime-sulfur and dry lime-sulfur rows in the last or maggot spray, May 12 and 21 and June 1, 15 and 30. The prepink applications were made after an infection period of 35 hours and the first application of the above treatments in a late bloom stage after an infection period of 40 hours. Dry lime-sulfur, Kolofog 6–100, and Kolofog 6–8–100 had 7.4, 0.4, and 17.8 per cent, respectively, of late secondary infection only. The other treatments had little or no secondary infection. Magnetic-Spray and Sulfrox are evidently identical materials.

h Lime-sulfur 1–50 was applied in the delayed dormant and pre-pink sprays, Apr. 27 and May 5 except on the Precipto block. Precipto ½ gal. per 100 with lime 5–100 was used in the lime-sulfur 1–60 thruout. Three applications of the above treatments were made May 11–16 and 24 and June 8. For the first of the three applications one-half of each block was sprayed in bloom after an infection period of 18 hours and the other half at petal fall after a second infection period of 24 hours. The 10-day application was made after an infection period of 58 hours. Arsenate of lead and lime, each 3–100, were applied in the last or maggot spray, June 27.

i Lime-sulfur 1–50 was used in the delayed dormant, Apr. 27. Four applications of the above treatments were made May 19, June 4 and 16, and July 2, the first five days after petal fall. No lime was used in the Kolofog.

on either side was 140. There was some fruit injury. One application of the iron sulfate mixture might be desirable, or two if they were not consecutively applied. Over-coverage must be guarded against and applications should not be made after mid-June.

If it seemed advisable to switch from lead arsenate to calcium arsenate to avoid arsenical residue, it would in all probability be

advisable to insure scab control before the July or first maggot spray was applied and then substitute a wettable sulfur, such as dry mix, Magnetic-Spray or Koppers flotation sulfur, using 3 pounds of lime for each pound of calcium arsenate.

LIQUID LIME-SULFUR WITH CERTAIN INSECTICIDES APPLIED AFTER INFECTION PERIODS

Spraying practices for scab are based on the assumption that sprays, to be effective, must precede and prevent infection. It has now become an established practice to spray with lime-sulfur after infection periods if circumstances have not permitted or justified the protection of the susceptible parts previously. Since lime-sulfur must necessarily be used with various insecticides, it becomes of interest to know what part the latter play in the effectiveness of the lime-sulfur.

Data relative to the effect of certain insecticides on the effectiveness of lime-sulfur when applied for the control of apple scab on McIntosh after an infection period are given in Table 7. The treatments were applied 24 to 30 hours after the wetting periods began. The application was made in the pink spray. The treatments were continued on their respective blocks for the remainder of the season except as noted otherwise. It is evident that arsenate of lead increased the effectiveness of lime-sulfur. The amount of scab was reduced from 18.4 per cent with lime-sulfur 1–50 alone to 9.8 per cent with lime-sulfur 1–50 and arsenate of lead 3-100. It would appear that the amount of control obtained with an application of lime-sulfur alone at the time of the infection period may be increased if the arsenate of lead combination is used in the following application. Calcium arsenate 3-100, magnesium arsenate 4-100, and cryolite 4-100 did not seem to affect materially the toxicity of the lime-sulfur.

DRY LIME-SULFUR

Of all the substitutes tested for liquid lime-sulfur 1-60, dry lime-sulfur 6-10-100 appears to be the best (Tables 5 and 6). It is apparently moderately eradicative, being about midway between liquid lime-sulfur and the dry wettable sulfurs (Table 6). Residue analyses show that dry lime-sulfur at this concentration gives a protection somewhere between liquid lime-sulfur 1-60 and 1-80 (Fig. 4). They were not widely variant. It caused somewhat less injury than lime-sulfur and left a very good finish of fruit. It has been

TABLE 7.— THE RELATION OF CERTAIN INSECTICIDES TO THE EFFECTIVENESS OF LIME-SULFUR WHEN APPLIED FOR THE CONTROL OF APPLE SCAB ON McINTOSH AFTER AN INFECTION PERIOD, OSBORN ORCHARD, ULSTER PARK, N. Y., 1933.*

TREATMENT†	NO. OF TREES COUNTED	TOTAL FRUIT COUNTED	PERCENTAGE OF SCAB			
			Slight	Medium	Bad	Total
Untreated‡	18	10,248	9.2	15.0	72.3	**96.5**
Lime-sulfur 1–50	34	31,805	4.2	7.5	6.7	**18.4**
LS and AL 3–100	10	9,254	2.7	3.8	3.4	**9.9**
LS and AL 3–100§	12	11,723	2.7	4.9	4.1	**11.7**
LS and CA 3–100	8	7,866	4.4	6.1	5.8	**16.3**
LS and MgA 4–100	9	6,563	4.7	7.4	5.4	**17.5**
LS and Cry. 4–100	13	10,515	5.8	8.5	6.7	**21.0**

* These data were taken from an experimental block which Dr. P. J. Chapman of this Station conducted for insect investigations.

† Abbreviations as follows: LS = lime-sulfur; AL = arsenate of lead; CA = calcium arsenate; MgA = magnesium arsenate; Cry. = Cryolite. The treatments were applied in the order named 24–30 hours after wetting period began. This was the pink spray, May 4. The same treatments were continued on their respective blocks for the remainder of the season except as noted otherwise. The applications were made calyx, May 17; 10-day, May 26; first codling moth, June 8.

‡ About 65 per cent of the scab classified as bad on the untreated apples enveloped the fruit, whereas only about 15 per cent of the bad scab of the sprayed trees barely exceeded the ¾ inch total diameter that threw them out of utility.

§ Lime-sulfur alone was used in the pink spray which was 14 days previous.

observed that dry lime-sulfur gives the best all around results on varieties like McIntosh. Satisfactory results were obtained using it with calcium arsenate 3-100 on McIntosh in 1933, but this combination cannot be used with safety on Baldwin.

WETTABLE SULFURS

The use of wettable sulfurs, particularly in the cover sprays or after petal fall, is a desirable modification of the lime-sulfur program in the Hudson Valley. *When timely applied,* dry mix, Koppers flotation sulfur paste, Koppers flotation dry wettable, Magnetic-Spray, Sulfrox, and Kolofog, at the dilutions used in these investigations, have proved to be, for all practical purposes, equally as effective as the lime-sulfur sprays under Hudson Valley conditions (Table 5). Ansul colloidal sulfur paste and Camden flotation sulfur paste appear equally protective but field trials have not been extensive. Cal-Mo-Sul has been shown in other experiments to be less effective than the other materials in this group in severe scab situations. Data show that *untimely applications* of wettable sulfurs may result in considerable scab, depending for the most part on the incidence of scab, the date of the last spray application, and the stage of fruit development at that time (Table 6).

Thoroness of coverage and frequency of application are more essential with the various wettable sulfurs than is the case with lime-sulfur. The sulfur residue studies indicated that wettable sulfurs may give less than, as much as, or greater sulfur deposits than lime-sulfur, depending principally on the rate of application and the concentration of the material used. Apparently the establishment of effective concentrations should be based primarily on the percentages of fine sulfur content.

In general, the above materials do not appreciably impair the foliage or injure the fruit when used with arsenate of lead. Conditions do arise when any sulfur material will give injury. Indications are, that with materials embodying only elemental sulfur, lime need not or should not be used more than 1 pound for each pound of lead arsenate. This would no doubt vary with the locality and the number of sprays to be applied. The flotation sulfurs may cause more cheek scald on the apples than materials that approach dry mix. They do give good finish of fruit, altho lacking somewhat in lustre. The use of Kolofog in the cover sprays has resulted in good foliage, but has left a heavy residue on the fruit which may be considered objectionable. Furthermore, it has been found, particularly in the later sprays, that lime should be added to eliminate arsenical injury. This may reduce the adhesiveness with a consequent lowering in the degree of scab control. Magnetic-Spray or Sulfrox have not been tested as thoroly as the above materials, but indications are that the results obtained with these materials as regards finish and injury will not be unlike those for dry mix. Ansul colloidal sulfur paste has given some injury to Baldwin foliage. Finish of fruit has been good in all tests. Cal-Mo-Sul is apparently a mild fungicide but injury has been observed, particularly on foliage.

WETTABLE SULFURS WITH CALCIUM ARSENATE

Of the materials tested, dry mix, Magnetic-Spray, and Koppers flotation sulfur proved the most satisfactory to use with calcium arsenate. Kolofog appeared more conducive to injury than the above materials. Indications are that the closer wettable sulfur sprays approximate dry mix, the greater is the compatability with arsenicals. Lime at the rate of 3 pounds for each pound of calcium arsenate must be used or defoliation and fruit drop may occur even on McIntosh. Great care should be taken in spraying to avoid injury to the foliage and fruit. The trees must be well pruned and vigorous if injury is

to be avoided. None of the materials are entirely desirable under all conditions when used with calcium arsenate.

SULFUR DUSTS

Blended Koppers flotation sulfur dust and Niagara Kolodust seem to have given satisfactory scab control (Table 8). The conditions under which dusts are effective are not unlike those for wettable sulfurs. The sulfur residue studies show that these sulfur dusts may be applied sufficiently heavy to foliage to give a total sulfur analyses comparable with that of sulfur sprays (Fig. 13). Data indicate that dusts may be decidedly less protective than wettable sulfurs on foliage and fruit (Figs. 14 and 15). This would in a measure depend on such factors as variety and time and frequency of application. While it is apparent that the fineness of the sulfur determines largely the degree of adhesiveness and the amount applied, observation indicates that this may not be the only desirable feature in a dust. Kolodusts, which contain bentonite, have given indication of value for application during a drizzly type of rain.

While dusts may be satisfactory where scab is not a problem, dusting is considered valuable in the main as a supplementary or emergency measure. General practice is confirmation enough that dusting is not an acceptable method of scab control. The latest development in spray machinery makes large-operation spraying more rapid than dusting and more effective.

COPPER SPRAYS

Coposil, one of the most satisfactory substitutes for bordeaux mixture, appeared to give commercial control of scab in more or less rigid tests (Table 5, Ser. 8, and Table 6, Ser. 6). Hydrated lime about 6-100 should always be used with Coposil. Copper phosphate mixture (copper phosphate, lime, bentonite 2-4-2-50) has given indications of being as good or better than Coposil in more limited trials. Basic copper sulfate, red copper oxide, and copper cyanide have also been tested but are not considered for the present because of the danger from severe injury, particularly with the latter two.

It would seem from adhesive studies of Coposil, copper phosphate mixture, red copper oxide, and bordeaux mixture made on Spy foliage by Dr. J. G. Horsfall of this Station that the degree of scab control obtained with these materials in the Hudson Valley is correlated with their adhesiveness. Apparently if the materials were on a com-

TABLE 8.— THE EFFECTIVENESS OF SULFUR DUSTS FOR APPLE SCAB CONTROL IN THE HUDSON VALLEY, 1932–1933.

TREATMENT*	NO. OF TREES COUNTED	TOTAL NO. OF FRUITS	PERCENTAGE SCABBED FRUITS			
			Slight	Medium	Bad	Total
Ser. 1, 1932, McIntosh (M. Albright)†						
Untreated	2	2,910	16.4	9.1	43.3	**68.8**
Lime-sulfur 1–60	3	4,615	0.1	0.0	0.0	**0.1**
Koppers dry 3–50	3	10,583	0.2	0.0	0.0	**0.2**
Kolokil 85–15	3	5,989	0.1	0.1	0.1	**0.3**
Ser. 2, 1932, Baldwin (E. B. Underhill)‡						
Untreated	1	2,345	16.6	2.6	5.8	**25.0**
Lime-sulfur 1–60	2	2,309	5.8	0.8	0.5	**7.1**
Dry mix 8–8–½	2	4,773	1.3	0.2	0.3	**1.8**
Cal-Mo-Sul 25–200	3	2,940	0.7	0.1	0.2	**1.0**
Kolokil dust 85–15	2	6,207	1.7	0.3	0.3	**2.3**
Koppers dust 85–15	2	3,186	1.7	0.1	0.1	**1.9**
Ser. 3, 1933, Red Delicious (J. Warner)§						
Untreated	2	2,159	17.7	4.9	8.7	**31.3**
Camden paste 10–100	5	1,698	0.6	0.5	0.1	**1.2**
Koppers dust 70–20–10	9	2,152	1.3	0.3	0.3	**1.9**
Kolodust 70–20–10	7	2,077	0.4	0.6	0.0	**1.0**

* Abbreviations as follows: Koppers dry = Koppers flotation dry wettable sulfur; Kolokil = Kolodust and arsenate of lead; Koppers dust = Blended flotation sulfur dust; Camden paste = Camden ferrox sulfur paste.

† Lime-sulfur 1–40 was used in the delayed dormant, May 2, and lime-sulfur 1–60 in the pre-pink, May 7. The above program began in the pink. Four applications of these treatments were made May 14 and 23 and June 2 and 15. Lime and arsenate of lead, each 3–100, were used alone on the sprayed blocks, while the Kolokil was used on the dust block in the last or first maggot spray, July 1.

‡ Lime-sulfur 1–60 was applied in the two sprays before bloom, Apr. 27 and May 9. There were four applications of the above sprays, May 21 and 31 and June 14 and July 7 and five of the dusts made after bloom, May 21 and 27, June 4 and 14, and July 7. The last dust and spray application of these treatments was unnecessary for scab control. Arsenate of lead 3–100 was added for the sprays and was used in the dusts 15–100 as designated.

§ Lime-sulfur 1–50 was applied in the two sprays before bloom, Apr. 26 and May 4. Three applications of the above treatments were made after petal fall, May 22 and June 3 and 17. Lime and calcium arsenate, each 3–100, were used in the Camden paste and 20–10, respectively, for each 70 pounds of sulfur dust.

parable adhesive basis with bordeaux mixture, the effective concentration of each should be based on its copper content.

Observations indicate that copper injury may vary tremendously from year to year, from orchard to orchard, and from tree to tree. Due probably to the low temperatures of the previous winter, the season of 1934, in which most of these observations were made particularly with reference to the above materials other than Coposil, was one in which both fruit and foliage were decidedly more susceptible than usual to copper injury. Obviously, varieties vary a

great deal as to the amount of injury manifested. Tests made on R. I. Greening, Baldwin, Winter Banana, Ben Davis, and McIntosh, except perhaps the latter, showed that not even the most promising copper materials were safe to use before a month after petal fall except in the delayed dormant spray. Coposil and copper phosphate mixture slightly russeted Ben Davis when applied two weeks after petal fall, but McIntosh fruits on grafts in the same trees showed perfect finish. Bordeaux 3-6-100 caused severe russeting to the Ben Davis.

In 1933 Coposil used with calcium arsenate 3-100 gave no appreciable injury to Baldwin except a slight network effect on the calyx end of the fruit with the petal fall application. The fruit had excellent finish and there was no foliage injury. Bordeaux mixture gave severe russeting even a month after bloom. In 1934 Coposil applied to the same block did not show as great a contrast with the bordeaux mixture. While the Coposil was distinctly less injurious than bordeaux mixture, it gave more injury in the calyx spray than it did in 1933 and some injury two weeks later. There was not the spread or consistent difference between it and bordeaux mixture in the later application a month after petal fall. This was also apparent in other blocks. It would seem that some of the variation in the amount of injury between the various copper materials could be attributed to differences in adhesiveness. This would depend, of course, upon the correlation with lime content, rain or humidity, temperature, and frequency of application. Coposil is apparently considerably less adhesive than bordeaux mixture. Coposil applied the latter part of June gives a high lustre and no appreciable residue, whereas bordeaux mixture may leave the fruit dull and with considerable residue. Copper phosphate tested in blocks of Greening, Ben Davis, and McIntosh seemed to show a slight margin of safety over the Coposil.

In 1933, Cal-Mo-Sul 6-100 reduced bordeaux (2-6-100) injury to a degree on Baldwin fruit, but in no way did the combination compare with Coposil. Cal-Mo-Sul 25-200 alone gave less russeting than lime-sulfur 1-60, but the fruit did not have the lustre of Coposil. Cal-Mo-Sul practically eliminated bordeaux injury to R. I. Greening fruit in the 1932 tests.

Copper injury from the use of weak bordeaux mixture in the cover sprays has been observed to be apparently minimized by repeated applications of the mixture or of lime alone. Oil, either mineral or

vegetable, has been observed to reduce injury from Coposil, red copper oxide and bordeaux.

ADHESIVE QUALITIES OF SULFUR SPRAYS AND DUSTS

It is evident that the protection of the host plant against scab is dependent on the amount of sulfur on the susceptible host parts during or after rains. It is common information that the degree of fineness of sulfur determines its distribution and adherence; that is, the sulfur that has the greatest number of particles in a unit weight will give the densest distribution and the greatest toxicity for that weight. Since these factors are evidently so important, studies of the comparative adhesiveness of the various sulfur spray materials seemed pertinent to the recommendation of effective concentrations.

The materials tested in these studies include the following: Liquid lime-sulfur, dry lime-sulfur, dry mix, Kolofog, Ansul colloidal sulfur paste, Koppers flotation dry wettable sulfur, Koppers flotation sulfur paste, Magnetic-Spray, blended Koppers sulfur dust, Magnetic-Sulfur dust, Super-Sulfodust, and Kolodust.

TECHNIC FOR SULFUR ANALYSES

Thruout these ensuing investigations on adhesiveness the leaf and apple samples were taken at random from the lower portions of the trees, except as noted. The leaves were selected as far as possible from the same position on the terminals after the growth was finished. The samples were collected from uniform trees and by the same individuals for each experiment or series. Two hundred leaves constituted a sample in 1932 and 250 in 1933. Fifty leaves were taken from each of four trees in 1932 and from each of five trees in 1933. The same trees were used thruout a given experiment. Duplicate samples were tested. Discs of 1 11/16 inches diameter were taken from the leaves, except as noted. In 1932, the leaves were stored in mason jars in carbon tetrachloride, and in 1933 they were rapidly dried in a ventilated hot-air oven, ground, and stored dry until such time as the sulfur could be removed with carbon tetrachloride.

The apple samples were composed of 50 fruits, 10 from each of five trees. They were immersed in carbon tetrachloride to remove the sulfur. All samples were thoroly rinsed with fresh carbon tetrachloride. The carbon tetrachloride was evaporated from the samples, the sulfur oxidized with sodium peroxide, and the sulfur precipitated

as barium sulfate. The extraction method by carbon tetrachloride removes the free or non-combined sulfur which is of importance from the spraying viewpoint, but this dissolution may be hindered with sulfur materials that contain protective colloids and solids other than sulfur. The technic thruout was standardized as far as possible to make all data comparable.

DISCUSSIONS OF FACTORS

Before attempting to interpret the results of these residue analyses, due consideration should be given to the limitations of such investigations. In view of the many variables in method, host, environment, and material which are encountered in such work as this, major emphasis should be placed on the single experiment or series. Each one seems surprisingly consistent and significant within itself but comparisons between them may be very misleading.

The same amount of rainfall may vary widely in effect because of differences in kind, frequency, and duration of the precipitations involved. Fine light rains of long duration appear to remove more sulfur than brief heavy downpours. Such differences cannot be expressed in tables or graphs. Wettable sulfurs require a pronounced drying period before rainfall to properly set them, and this variable factor is of great importance in determining their adhesiveness.

Such studies on foliage as are reported herein were made on matured leaves. To what extent the findings are applicable to spray materials and practices during the period of rapid host growth is open to conjecture. In the spring, growth may be a more important factor than either rainfall or adhesiveness of materials in determining the frequency and concentration of treatment. Weather records indicate that 2 to 3 inches of rain are about the maximum to be expected between sprays. Thus it is apparent that even the materials or concentrations of materials that exhibit the greater sulfur residues would be ineffective in scab control due to new growth of the host before the factor of amount of protection becomes significant. Of course the greater sulfur residue would be an advantage against summer or fall infections.

The adhesiveness of any given material will vary with differences in leaf and fruit characteristics of apple varieties, and it will not necessarily be the same for leaves as for the fruit in the same variety. For example, Baldwin leaves appear to retain sulfur longer on their

undersides than do McIntosh leaves. Spray materials are less rapidly washed from Baldwin fruit than from McIntosh fruit.

There is no doubt considerable variation in sulfur distribution among the sulfur fungicides. The data as taken give no conception of the distribution of sulfur over the leaf surface. In general, dusts and wettable sulfurs tend to collect by the midribs and veinlets. While these portions of the leaf are susceptible to infection longest and sulfur can be effective over an area larger than it actually contacts, still it is conceivable that at times this type of distribution would not be entirely protective. In consequence, tho the total amounts of deposited sulfur per unit area may be the same for some of these materials as for the sprays containing lime-sulfur, the more uniform distribution in the case of the latter should give better protection against scab infection. In this connection too, it must be borne in mind that sprays containing lime-sulfur may have a very considerable after-infection fungicidal value at the time of application which wettable sulfurs and the like do not have. That is, such data as is reported herein on adhesiveness should not be taken as the sole basis for comparing the value of materials.

Beyond a certain point an increase in the number of sulfur particles per unit area may be expected to increase the *rate* of loss. Thus it is apparent that the amount of any material applied influences the rate of early loss.

Both the adhesiveness and effectiveness of elemental sulfur may be markedly altered by changes of physical state or additions of other materials. Proprietary sulfur fungicides are characterized by the inclusion of "spreaders," "stickers," and fillers, or by patented processing. While some of the products appear to be well standardized, the nature and content of such modifying agents are subject to change in such materials at any time. Also, consideration must be given to the influence of insecticides and correctives as used in the different tests.

These residue studies establish a comparative basis for evaluating the materials as to adhesiveness of their sulfur deposits. It is hoped that the values obtained may serve as a foundation for subsequent studies of the physical and chemical character of sulfur residues. More knowledge of residue characteristics will lead to a better understanding of fungicidal effectiveness of sulfur spray materials.

SPRAYS CONTAINING LIME-SULFUR

The amount of sulfur found adhering at successive intervals to McIntosh foliage from the application of sprays containing lime-sulfur tends to be in proportion to the dilution or concentration applied (Fig. 4). It is apparent that lime-sulfur 1-40, 1-60, and

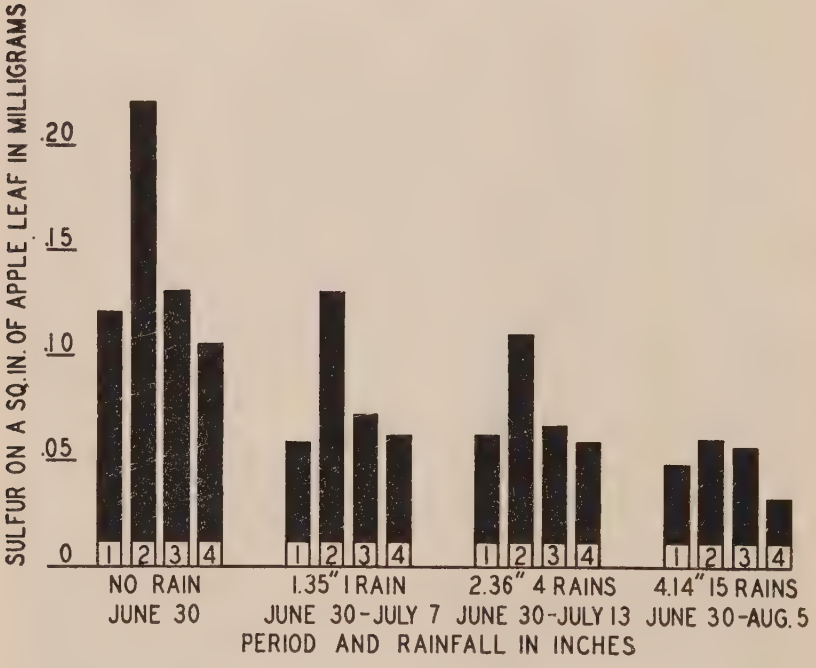

FIG. 4.—COMPARATIVE ADHESIVENESS OF SPRAYS CONTAINING LIME-SULFUR AT SUCCESSIVE INTERVALS WHEN APPLIED TO MCINTOSH FOLIAGE.

Warner Orchard, Poughkeepsie, N. Y., 1931. **1,** dry lime-sulfur 3-5-50; **2,** lime-sulfur 1–40; **3,** lime-sulfur 1–60; and **4,** lime-sulfur 1–80. The treatments were applied to their respective blocks in the five previous sprays except the dry lime-sulfur in which case the trees had not been sprayed previously. Arsenate of lead 3–100 was used in all sprays.

1-80 are washed or weathered off at approximately the same rate. Lime-sulfur 1-40 gives about 40 per cent greater sulfur residue than lime-sulfur 1-60 and about 50 per cent more than lime-sulfur 1-80 until 2 inches or more of rain have fallen.

Dry lime-sulfur 3-5-50 appears to give a protection somewhere between the liquid lime-sulfur 1-60 and 1-80. They are not widely variant.

WETTABLE SULFURS

Dry mix was found decidedly less adhesive than lime-sulfur in proportion to the original amount of sulfur applied in applications made on McIntosh and Baldwin foliage (Figs. 5, 6, 12, or 13). The

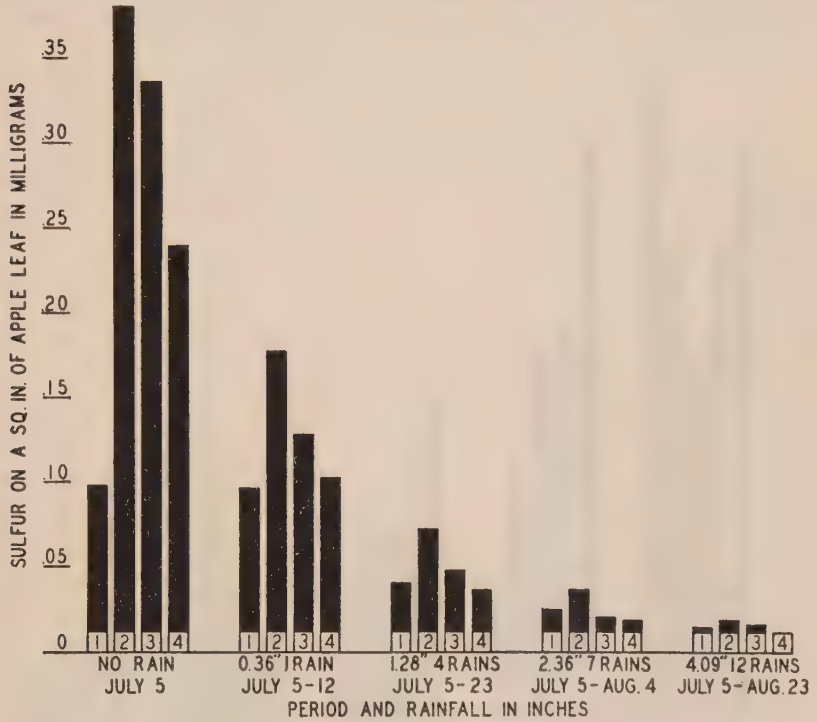

FIG. 5.—THE COMPARATIVE ADHESIVENESS OF LIME-SULFUR AND SEVERAL STRENGTHS OF DRY MIX AT SUCCESSIVE INTERVALS TO MCINTOSH FOLIAGE.

Hubbard Orchard, Poughkeepsie, N. Y., 1932. **1,** lime-sulfur 1–60; **2,** dry mix 16–8–½; **3,** dry mix 12–8–½; and **4,** dry mix 8–8–½. The treatments were applied to their respective blocks in the three previous sprays. Arsenate of lead 3–100 was added to all the sprays.

fact that 0.36 inch of rain (a good shower) removed about one-half or more of the dry mix but practically none of the lime-sulfur is evidence that a large portion of dry mix is too coarse to stick well. The rate of loss of the different concentrations of dry mix (16-8-½, 12-8-½, and 8-8-½) does not appear significantly variable (Fig. 5). The degree of subsequent adherence after the heavy initial loss was not unlike lime-sulfur. It is evidently possible to so apply dry mix that it will give a sulfur residue comparable with that of lime-sulfur.

Lime-sulfur 1-40, Kolofog 8-100, Ansul sulfur 3-100, Koppers dry wettable 6-100, and dry mix 12-8-½ contain about 6.7, 2.7, 2.7, 5.2, and 12 pounds of sulfur, respectively, per 100 gallons of material. These materials at the given concentrations were compared in applications on McIntosh foliage (Fig. 6). Altho the initial analyses are

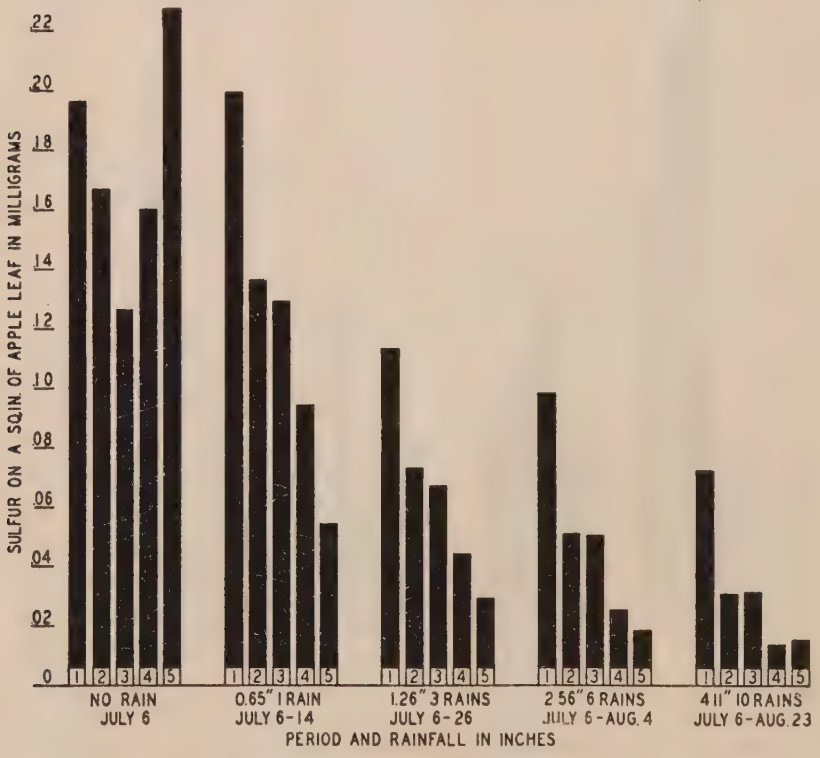

Fig. 6.—The Comparative Adhesiveness of Various Sulfur Fungicides at Successive Intervals to McIntosh Foliage.

Craft Orchard, Lattintown, N. Y., 1932. **1**, lime-sulfur 1–40; **2**, Kolofog 8–6 (lime)–100; **3**, Ansul sulfur 3–100; **4**, Koppers dry wettable 6–100; and **5**, dry mix 12–8–½. The treatments were applied to their respective blocks in the three previous sprays. Arsenate of lead 3–100 was used with all materials.

not in accord with the concentration of sulfur applied for each material, it appears that after the first rain the rank of the materials in adherence is correlated with the amount of fine sulfur they contain. But due allowance must be made for such factors as arsenate of lead, lime, and spreaders or stickers. The amount of sulfur in the initial

applications of the above materials was reduced about 42, 56, 47, 72, and 86 per cent, respectively, with 1.26 inches rainfall. At the concentrations used the above wettable sulfurs gave about 68, 65, 47, and 27 per cent, respectively, as much total sulfur protection as the lime-sulfur at the end of 0.65 inch of rain. These percentages decreased somewhat after about 2½ inches of rain. It is interesting to note that these materials, particularly the wettable sulfurs, were not widely variant in their rate of loss after the initial rain. This trend was also evident in Figs. 7 to 9. The sulfur from lime-sulfur applications is evidently the most adhesive in proportion to the amount applied and comes off very slowly.

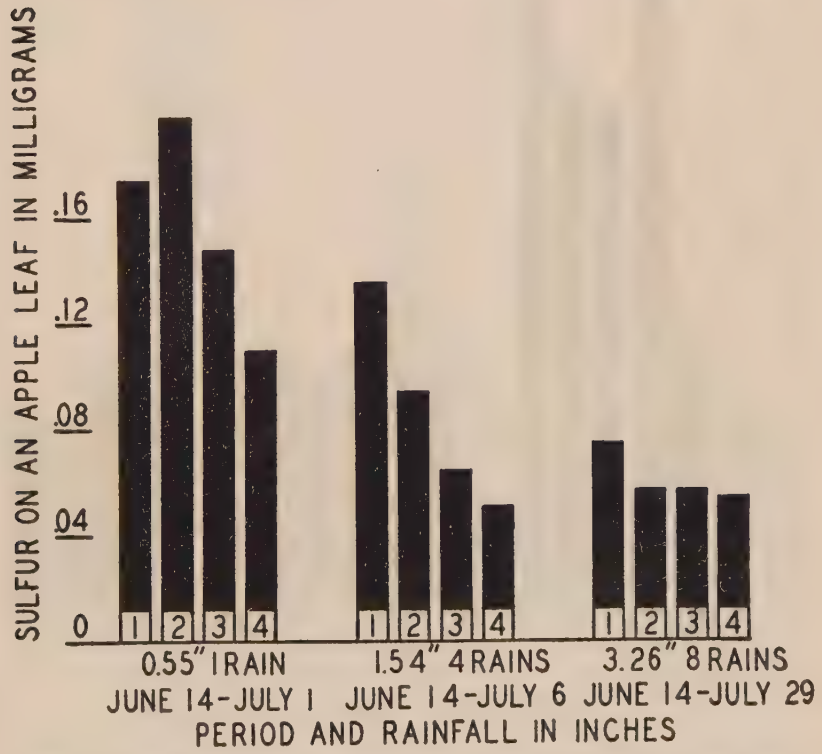

FIG. 7.—THE COMPARATIVE ADHESIVENESS OF VARIOUS SULFUR FUNGICIDES AT SUCCESSIVE INTERVALS TO McINTOSH FOLIAGE.

Didell Bros., Poughkeepsie, N. Y., 1933. 1, lime-sulfur 1–60; 2, Koppers dry wettable 5–100; 3, Koppers paste 10–100; and 4, dry mix 10–3–1. The treatments were applied to their respective blocks in the three previous sprays. Calcium arsenate 3–100 was used with these materials.

The data (Fig. 7) indicate that it is possible for Koppers dry wettable 5-100 to give a greater sulfur residue at successive intervals than Koppers flotation paste 10-100. In tests in 1931 (Bulletin No. 604 of this Station) the variation in sulfur residue between Kolofog 8-100, Koppers flotation paste 10-100, dry lime-sulfur 3-5-50, and

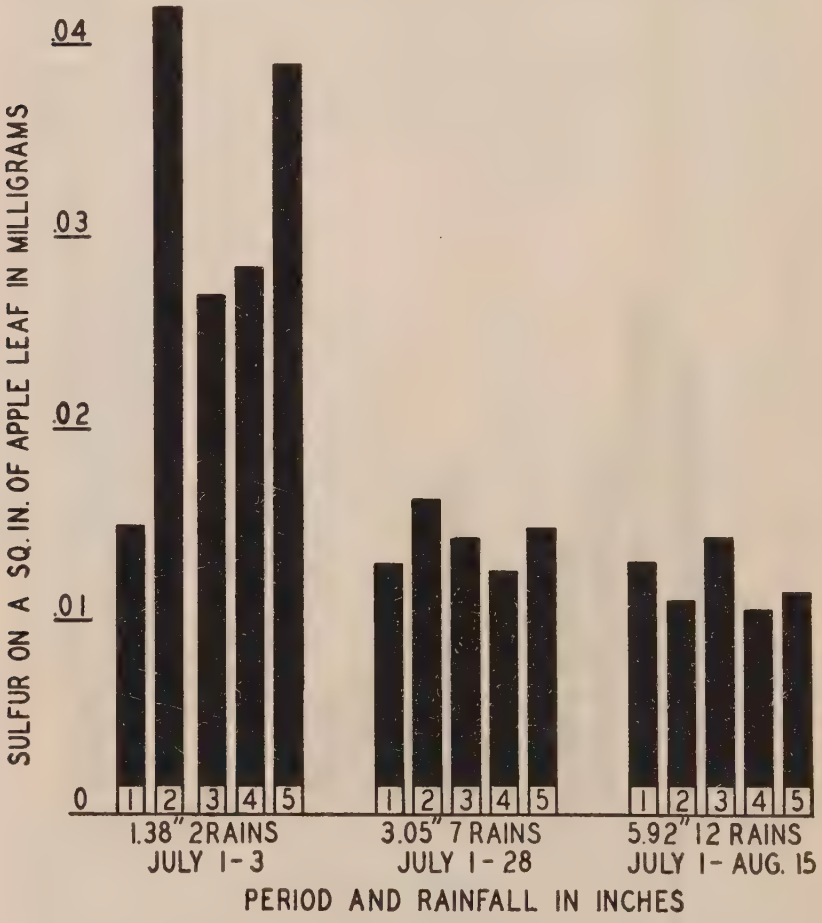

Fig. 8.—The Comparative Adhesiveness of Various Sulfur Fungicides at Successive Intervals to Baldwin Foliage.

Young Orchard, Marlboro, N. Y., 1933. **1**, lime-sulfur 1–60; **2**, dry mix 10–3–1; **3**, Magnetic-Spray 6–100; **4**, Koppers dry wettable 5–100: and **5**, Kolofog 6–100. The treatments were applied to their respective blocks in the four previous sprays. Calcium arsenate 3–100 and lime 6–100 were used in all the sprays.

liquid lime-sulfur 1-60 was apparently not materially significant. Dry mix 16-8-1 gave indication of as good or better protection than the above materials.

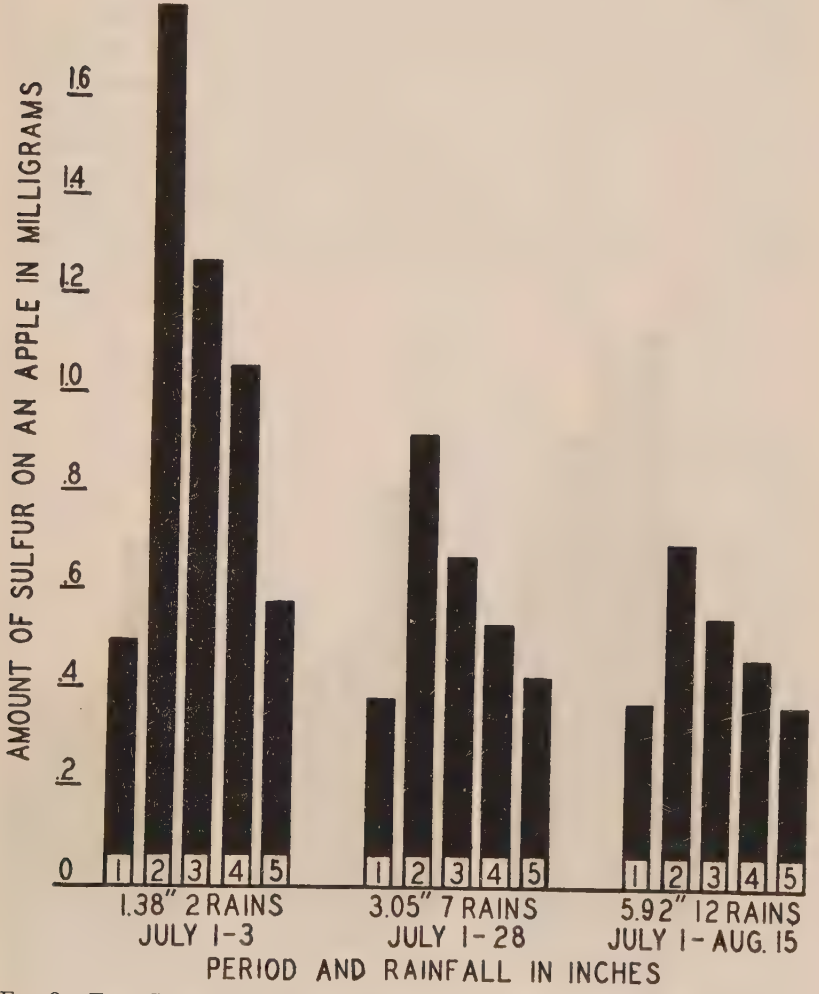

Fig. 9.—The Comparative Adhesiveness of Various Sulfur Fungicides at Successive Intervals to Baldwin Fruit.

Young Orchard, Marlboro, N. Y., 1933. 1, lime-sulfur 1–60; 2, dry mix 10–3–1; 3, Magnetic-Spray 6–100; 4, Koppers dry wettable 5–100; and 5, Kolofog 6–100. The two diameters of the apples were 1.3x1.44, 1.48x1.68, and 1.55x1.90 inches for the three dates of sampling, respectively. The above treatments were applied to their respective blocks in the four previous applications. Lime 6–100 and calcium arsenate 3–100 were used in all the sprays.

In general, wettable sulfurs tended to adhere to Baldwin fruit more than they did to Baldwin foliage, altho the analyses for the initial sulfur residues are not available (Figs. 8, 9, or 11). It is not only a question of amount of residue, but also rate of loss. After about 3 inches of rain, the rate of loss is not widely variant on foliage or fruit and the materials tend to reach a more or less common level. Prior to this time the materials appear to be on a comparative basis, at least after 1.4 inches of rain, and the rate of loss is somewhat heavier on the foliage than on the fruit. This apparent relationship on Baldwin would not necessarily apply to other varieties, such as McIntosh. Not only do the foliage characteristics of the two varieties differ, but the Baldwin fruit tends to be rough or non-waxy while

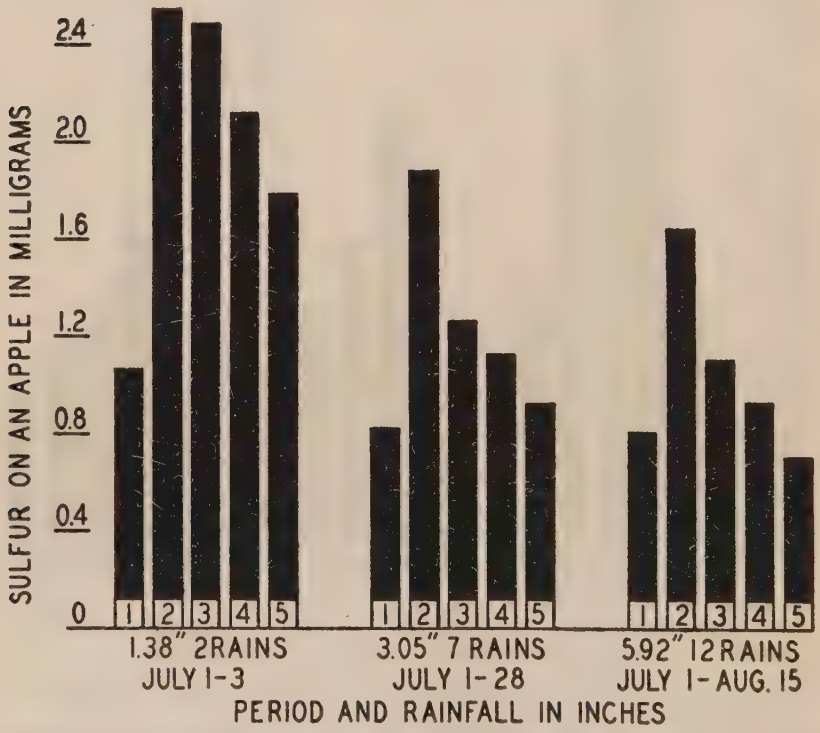

Fig. 10.—The Comparative Adhesiveness of Various Sulfur Fungicides to Baldwin Fruit When the Data are Computed on the Basis of 10 Pounds of Sulfur in 100 Gallons of Water.

Data from Fig. 9. 1, lime-sulfur; 2, Kolofog; 3, Koppers dry wettable; 4, Magnetic-Spray; and 5, dry mix.

McIntosh fruit is smooth or waxy. This point will be discussed further in relation to arsenical residues.

It is evident that wettable sulfurs at concentrations recommended in the Hudson Valley at present will deposit as much or more total sulfur on Baldwin fruit than lime-sulfur 1-60 (Fig. 9). The materials gave sulfur residues in the order of their sulfur contents which

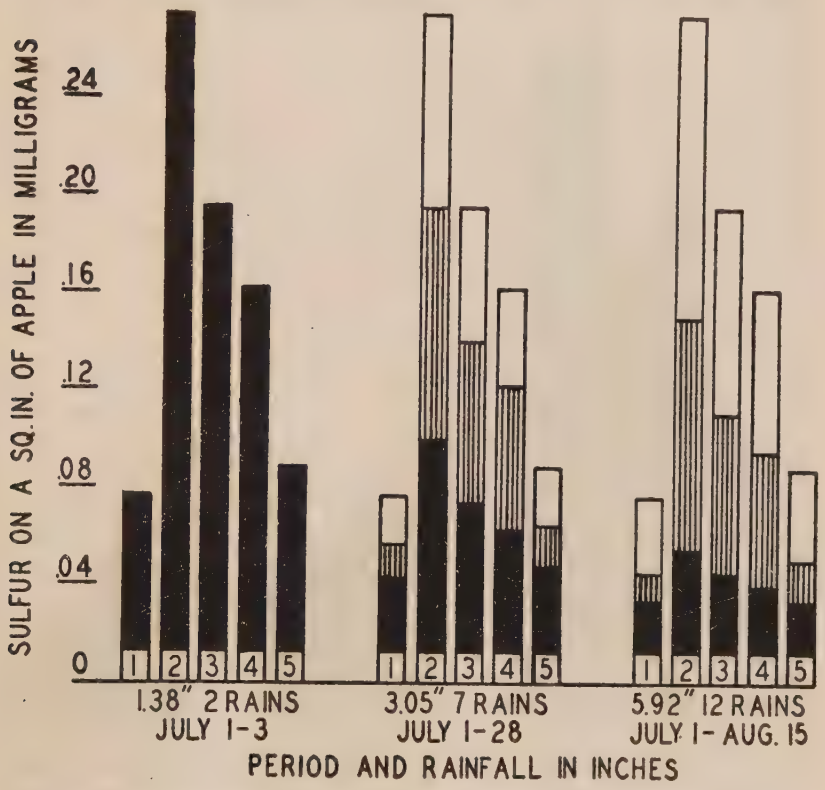

FIG. 11.—THE RELATION OF GROWTH AND RAINFALL (WEATHERING) TO THE AMOUNT OF SULFUR PER SQUARE INCH AT SUCCESSIVE INTERVALS ON BALDWIN FRUIT.

Young Orchard, Marlboro, N. Y., 1933. ☐ Sulfur reduction per square inch due to growth. ▥ Sulfur reduction per square inch due to rainfall (weathering). ■ Sulfur present per square inch. **1**, lime-sulfur 1–60; **2**, dry mix 10–3–1; **3**, Magnetic-Spray 6–100; **4**, Koppers dry wettable 5–100; and **5**, Kolofog 6–100. The above treatments were applied to their respective blocks in the four previous sprays. Lime 6–100 and calcium arsenate 3–100 were used in all the sprays.

are as follows: Kolofog, 6-100, about 2 pounds; Koppers dry wettable, 5-100, 4.3 pounds; Magnetic-Spray, 6-100, 6 pounds; and dry mix 10-3-1, 10 pounds. If these materials were figured on the basis of 10 pounds each of actual sulfur per 100 gallons, their order is actually reversed (Fig. 10). For example, Kolofog the least

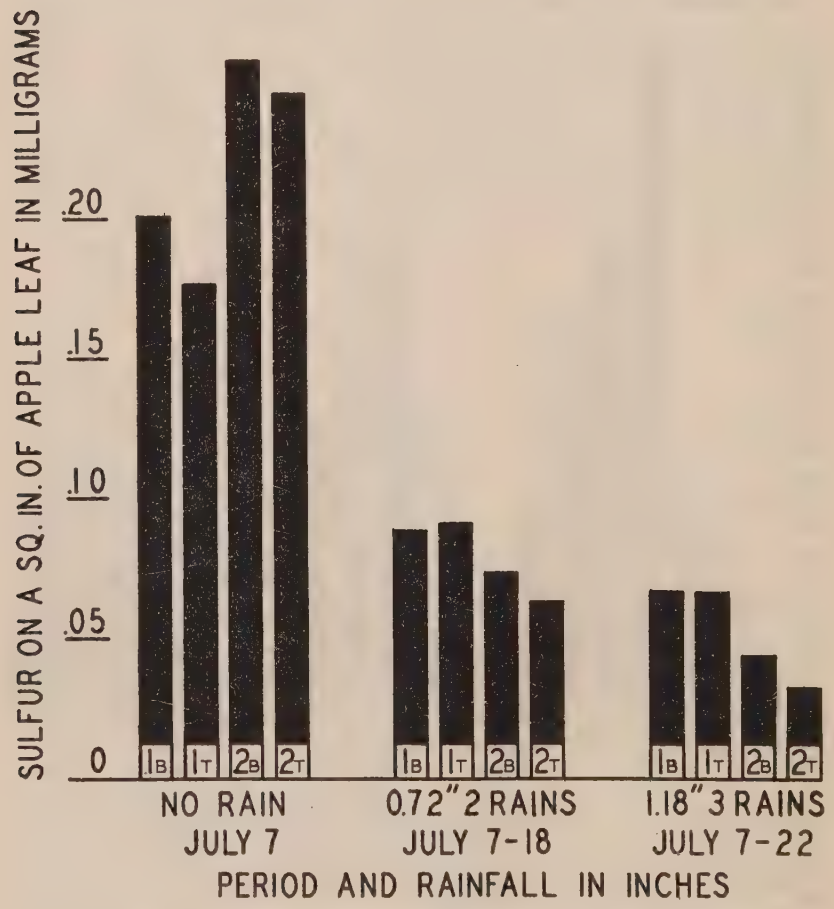

Fig. 12.—The Comparative Adhesiveness of Sulfur Materials at Successive Intervals on the Foliage at the Bottom and the Top of Baldwin Trees.

E. B. Underhill Orchard, Poughkeepsie, N. Y. **B**, leaf samples taken from bottom of tree; **T**, leaf samples taken from top of tree; **1**, lime-sulfur 1–60; and **2**, dry mix 8–8–½. The above sprays were applied to their respective blocks in the three previous applications. Arsenate of lead 3–100 was used in the sprays.

protective from the amount of sulfur standpoint would then probably give the greatest sulfur residue.

In considering sulfur distribution on sprayed fruit, there is a growth factor to be taken into account in addition to rain and weathering. The data indicate that, after the excess sulfur is removed, 40 per cent or more of the reduction in amount of sulfur per unit area may be due to redistribution caused by growth alone (Fig. 11). The degree of redistribution would depend, of course, on the length of time between sprays, the frequency of rainfall, and the rate of growth for that period. The percentage would no doubt be greater with the more adhesive materials. Growth becomes an increasingly important factor with each successive rain period and consequent weathering after a given application.

The data show that rate of sulfur removal, at least for lime-sulfur and dry mix, is the same for the top and bottom of the trees (Fig. 12).

SULFUR DUSTS

Comparative data relative to the adhesiveness of sulfur in dusting and spraying practices are presented in Fig. 13. Very thoro dust applications were made in the morning in heavy dew and from both sides of the trees. From 3 to 5 pounds of dust were applied to each tree (18 years old). Apparently, the physical properties of the dusts determined in a large measure the amounts applied. The finer dust required less material by weight to give what appeared to be equivalent coverage. It is evident that it is possible to dust Baldwin foliage at least and have more sulfur residue at successive intervals than with spraying.

In Fig. 14, where the data were taken from 16-year-old McIntosh trees that had been dusted lightly but thoroly when practically dry and the sulfur afterward set by dew, it will be observed that again the finest dust was applied least heavily. While it would appear that Koppers blended dust has materially the best dusting properties, it is also true that Kolokil might adhere the best to wet foliage because of the bentonite, particularly if it were to rain shortly afer the application or before the sulfur set.

Even tho the coarse sulfur dusts will be applied more heavily than the finer grades it is probable that no better protection against scab will be obtained. It is apparent that 0.14 inch of rain reduced blended Koppers dust, Magnetic-Dust, Super-Sulfodust, and Niagara Kolo-

dust, each 70-20-10 (sulfur, lime, calcium arsenate), to a more or less common level and to about half that of Koppers dry wettable 5-100 when they were applied to McIntosh foliage as mentioned above (Fig. 14). In contrast with about 30 per cent of the Koppers dry wettable, 57, 78, 73, and 71 per cent of the above dusts, respectively, were removed with this shower. The rate of loss after the initial loss was about the same for each.

The sulfur analyses of the McIntosh fruit were not unlike those for the foliage, except in amount, in that there may be only about half

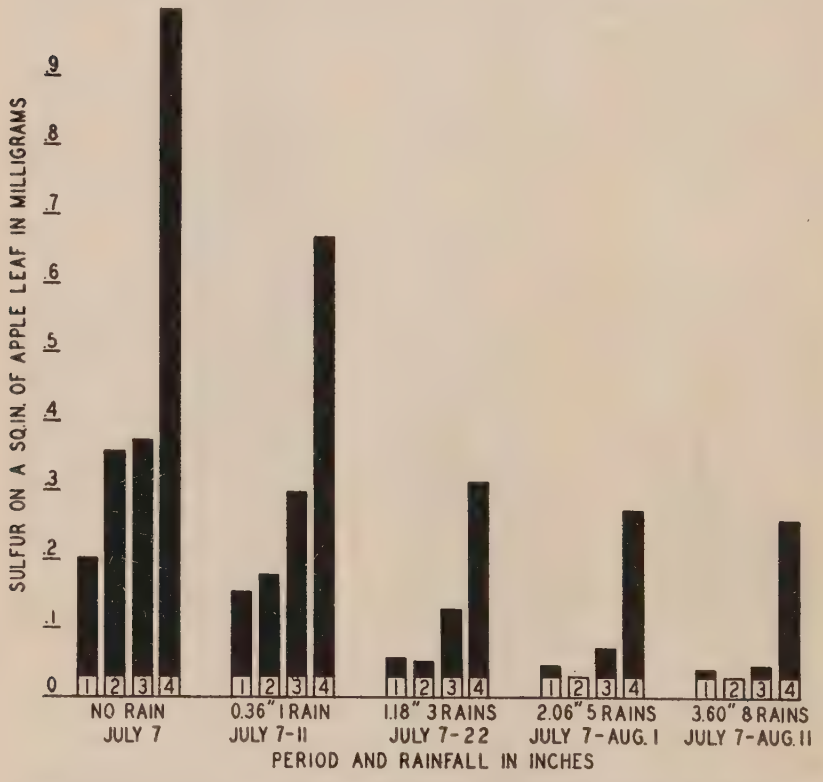

Fig. 13.—The Comparative Adhesiveness of Sulfur Dusts with Other Fungicides at Successive Intervals to Baldwin Foliage.

E. B. Underhill Orchard, Poughkeepsie, N. Y., 1932. **1**, lime-sulfur 1–60; **2**, dry mix 8–8–½; **3**, blended Koppers dust 85–15; and **4**, Kolokil 85–15. The above sprays were applied to their respective blocks in the three previous applications and the dusts in four. Arsenate of lead 3–100 was used in the sprays and as designated above in the dusts.

as much sulfur on the fruit using a Koppers blended dust 70-20-10 as compared to the Koppers dry wettable spray 5-100 with 3 pounds each of lime and calcium arsenate (Fig. 15). It is evident that at this time there was so little sulfur residue from the dust that the rate of loss was less than from the wettable sulfur. A comparison of the sulfur residue on the foliage and fruit indicate that it was not unlike that for the Baldwin foliage and fruit (Figs. 8 and 9).

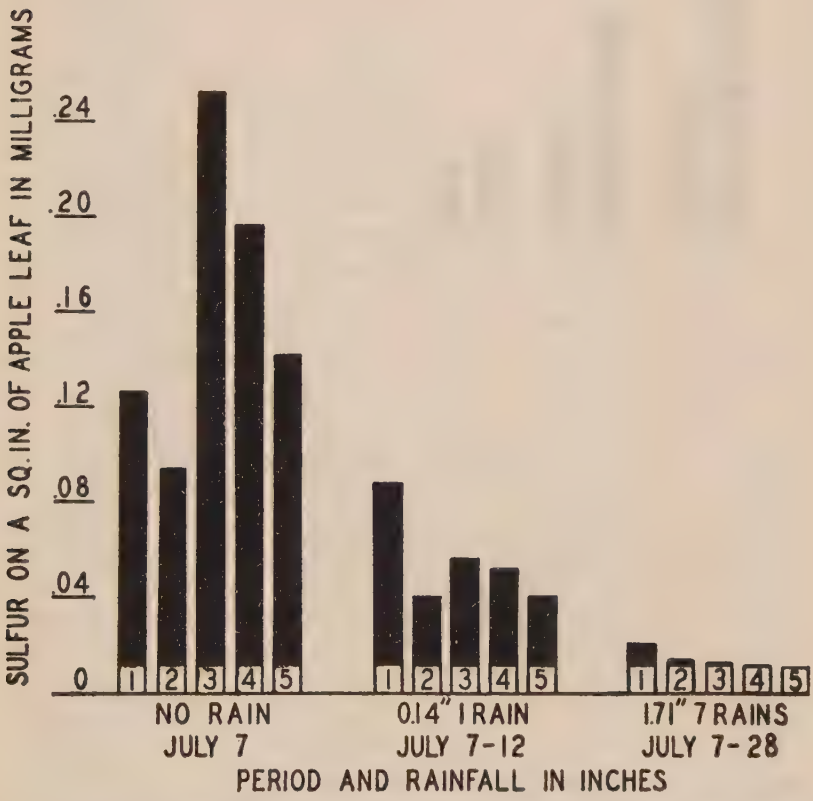

Fig. 14.—The Comparative Adhesiveness of a Wettable Sulfur and Various Sulfur Dusts at Successive Intervals to McIntosh Foliage.

Warner Orchard, Poughkeepsie, N. Y., 1933. 1, Koppers dry wettable 5–100; 2, blended Koppers dust 70–20–10; 3, Magnetic-Dust 70–20–10; 4, Super-Sulfodust 70–20–10; and 5, Niagara Kolodust 70–20–10. The last previous application to the above blocks was made June 10 when Koppers dust was applied. Lime 6–100 and calcium arsenate 3–100 were used in the spray and as noted above, respectively, with sulfur in the dust.

SULFUR FUNGICIDES AND ARSENICAL RESIDUES [3]

Data pertaining to the relative adherence of calcium arsenate at successive intervals when applied with various sulfur fungicides to Baldwin and McIntosh fruit are given in Figs. 16, 17, and 18, which are identical with Figs. 8 or 9, 7 and 14, or 15, respectively. The apple samples were composed of 25 fruits, 5 from each of five trees. It is evident that there may be considerable variation in the arsenical residue with the several materials, particularly with the first rains, but the biological significance is open to conjecture. There is a marked difference between the lime-sulfur residues with lead arsenate and the lime-sulfur residues with calcium arsenate. It is apparent that lime-sulfur and arsenate of lead in combination are very resistant to rain and weathering. Applications made to Baldwin fruit June 29 were not reduced below the tolerance by September 28 by 19 inches of rain from 26 rains. The lime-sulfur and calcium arsenate application was at an equivalent point with about 6 inches of rain from 12 rains. Lime-sulfur with calcium arsenate may give a higher arsenical residue at first than the wettable sulfurs but, generally speaking, indications are that it would eventually leave about the same or less arsenical residue (Figs. 16 and 17).

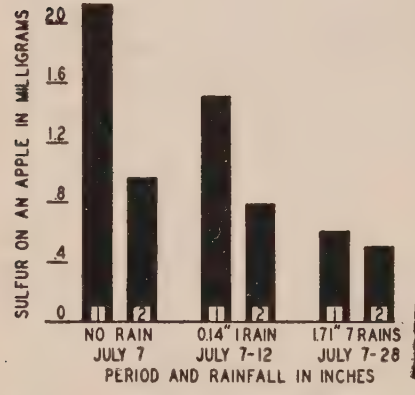

FIG. 15.—THE COMPARATIVE ADHESIVENESS OF A WETTABLE SULFUR AND A SULFUR DUST AT SUCCESSIVE INTERVALS TO MCINTOSH FRUIT.

Warner Orchard, Poughkeepsie, N. Y., 1933. 1, Koppers dry wettable 5–100; and 2, blended Koppers dust 70–20–10. The last previous application to the above blocks was made June 10 when Koppers dust was applied. Lime 6–100 and calcium arsenate 3–100 were used in the spray and as noted above, respectively, with sulfur in the dust.

It appears that the wettable sulfur that leaves the least sulfur on the fruit may give the greatest arsenical residue, and vice versa, at least at a certain stage of weathering (Figs. 7 to 9, 16 and 17). This observation is most evident with dry mix. Kolofog on the Baldwin

[3] The arsenic analyses were made by G. W. Pearce of the Chemistry Division of this Station.

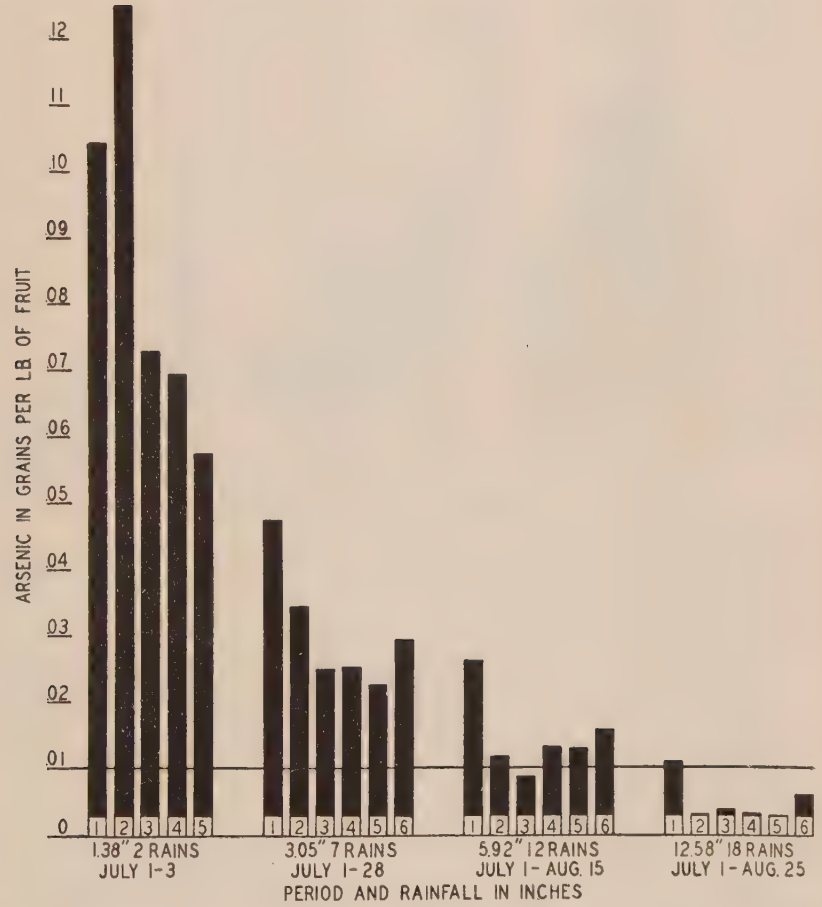

FIG. 16.—THE RELATIVE ADHERENCE OF CALCIUM ARSENATE AT SUCCESSIVE INTERVALS WHEN APPLIED WITH VARIOUS SULFUR FUNGICIDES TO BALDWIN FRUIT.

Young Orchard, Marlboro, N. Y., 1933. **1**, lime-sulfur 1–60 and lead arsenate 3–100; **2**, lime-sulfur 1–60; **3**, Magnetic-Spray 6–100; **4**, Koppers dry wettable 5–100; **5**, dry mix 10–3–1; and **6**, Kolofog 6–100. The two diameters of the apples were 1.3x1.44, 1.52x1.77, 1.67x1.97, and 1.81x2.17 inches for the four dates of sampling, respectively. The above treatments were applied to their respective blocks in the four previous sprays. Calcium arsenate 3–100 and lime 6–100 were used with these materials except as noted. The arsenate of lead was used with Koppers dry wettable in the four sprays previous to the lime-sulfur application.

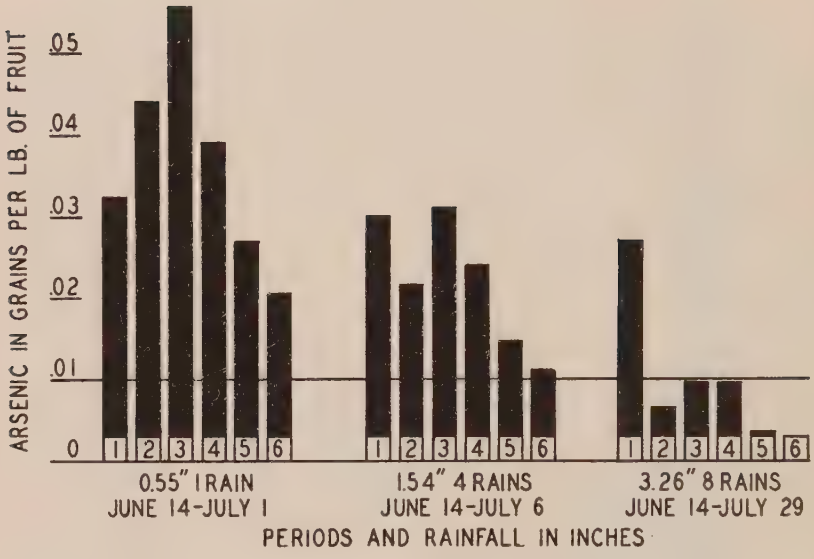

Fig. 17—The Relative Adherence of Calcium Arsenate at Successive Intervals when Applied with Various Sulfur Fungicides to McIntosh Fruit.

Didell Bros. Orchard, Poughkeepsie, N. Y., 1933. **1,** lime-sulfur 1–60 and lead arsenate 3–100; **2,** lime-sulfur 1–60; **3,** Kolofog 6–8 (hme)–100; **4,** dry mix 10–3–1; **5,** Koppers paste 10–100; and **6,** Koppers dry wettable 5–100. The two diameters of the apples were 1.37x1.48, 1.46x1.53, and 1.69x1.9 inches for the three dates of sampling, respectively. The above treatments were applied to their respective blocks in the three previous sprays. Calcium arsenate 3–100 was used with the materials except as noted.

fruit left the least sulfur residue and the largest arsenical residue of the wettable sulfurs, but the bentonite must be taken into consideration in this instance (Figs. 9 and 16). On the McIntosh foliage the Koppers dry wettable, Koppers paste, and dry mix, in order, gave decreasing sulfur residues. This order was reversed, however, with the arsenical residue on the fruit (Figs. 7 and 17). With due allowance for the growth factor, it is evident that two to three times as much washing is required to remove the equivalent arsenical residue from a variety with a skin like a Baldwin as compared to the waxy skin of the McIntosh (Figs. 16 and 17). It took between 6 and 12 inches of rain to reduce the calcium arsenate residue on Baldwin below the tolerance, whereas about 3 inches were sufficient on the McIntosh.

The data show that an application of Koppers blended dust 70-20-10 (sulfur, lime, calcium arsenate) in the evening or when the fruit is about dry in the morning will give little more than the tolerance as compared to 10 times the tolerance with Koppers dry wettable 5-100 with 3 pounds each of lime and calcium arsenate (Fig 18). A shower of 0.14 inch is enough to reduce the arsenical residue of the dust block below tolerance. There was no appreciable accumulative arsenical residue before the above treatments were made.

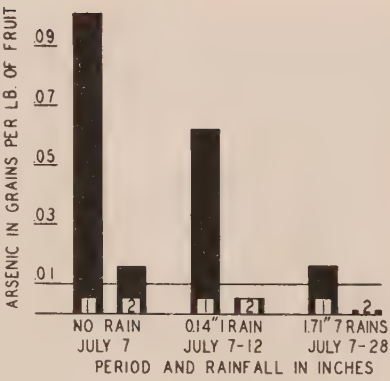

Fig. 18.—The Relative Adherence of Calcium Arsenate at Successive Intervals when Applied with a Wettable Sulfur and a Sulfur Dust to McIntosh Fruit.

Warner Orchard, Poughkeepsie, N. Y., 1933. 1, Koppers dry wettable 5–100; and 2, blended Koppers dust 70–20–10. The two diameters of the apples were 1.6x1.6, 1.56, 1.71, and 1.66x1.92 inches for the three dates of sampling, respectively. The last previous application to the above blocks was made June 10 when Koppers dust was applied. Lime 6–100 and calcium arsenate 3–100 were used in the spray and as noted above respectively with sulfur in the dust.

EFFECT OF SPRAYS APPLIED DURING BLOOM

Insufficient protection during the long interval that frequently occurs between the pink and calyx sprays, particularly with long-blooming varieties such as Delicious and Rome Beauty, raises the question of the feasibility of spraying or dusting during bloom. The periods between the pink and calyx sprays for McIntosh have been 8 to 10, 18 to 22, 9 to 14, 14 to 19, and 5 to 11 days for the years 1930 to 1934, respectively. In the season of 1934 sudden bloom eliminated the pink spray for most growers and an abnormally long bloom period due to winter injury necessitated spraying before petal fall. Since the maximum danger from scab in the Hudson Valley is simultaneous with the blossom periods and since the pink sprays tend to be applied early, it is evident that applications of spray in bloom are worthy of consideration to the control of primary infection. During the five years of 1930 to 1934, there were infection periods during bloom in two seasons, 1931 and 1934, but this was

due solely to lack of wetting periods. While there are many instances where materials have been applied during the blossoming period without noticeably reducing the crop, the status of the practice seems uncertain.

Some tests were conducted chiefly from the growers' points of view to determine the effect of fungicides on the commercial set of fruit under Hudson Valley conditions. The points given particular consideration were the toxicity of the materials to pollen in the laboratory and the approximate relation between the opening of the blossom buds, pollination by bees, and the time that fungicides could be applied without reducing the set.

LABORATORY METHODS AND RESULTS

Toxicity tests of Super-Sulfodust, Koppers dry wettable, and bordeaux mixture to Red Delicious pollen are recorded in Table 9. The tests were made in liquid medium on glass slides, flat and inverted (hanging drops), and on agar medium. The liquid medium was a 10 per cent commercial cane sugar solution and the agar medium was composed of 1½ per cent agar shreds added to the sugar solution.[4] The pollen suspension was so made that the ultimate dilution was about 50 pollen grains to the field of the low-power microscope objective. There was difficulty in getting approximately the same amount of dust for each test and the dust sulfur particles tended to settle toward the margin of the drops. The Koppers dry wettable sulfur which would be ordinarily used 5-100 in the field was reduced to 2-100 in order that the pollen grains might be visible with the microscope. Duplicate set-ups were placed in large moist chambers sealed with water for germination to take place. The tests were made at room temperature. Examination was made after an interval of 22 to 28 hours.

Data show that bordeaux 1-3-100 was absolutely toxic and this fact held true at decidedly lower concentrations. It is evident that sulfur was also toxic under given conditions. There was some germination in the tests with Super-Sulfodust and Koppers dry wettable, depending upon the vitality of the pollen, but the germ tubes, as far as the liquid medium was concerned, were very short, varying from mere protrusion to about 5 to 10 times the diameter of the pollen

[4] MacDaniels, L. H., and Furr, J. R. The effect of dusting sulfur upon the germination of the pollen and the set of fruit of the apple. *Cornell University Agr. Exp. Sta. Bul. No. 499, 1930.*

grain itself. It is very doubtful if the germ tubes of the pollen so affected would ever penetrate the style and bring about fertilization. The germ tubes of the untreated pollen grains were so long and vigorous as to make measurements difficult.

TABLE 9.—RELATIVE EFFECT OF SULFUR AND BORDEAUX UPON GERMINATION AND LENGTH OF GERM TUBES OF RED DELICIOUS POLLEN.

TREATMENT*	GERMINATION OF GERM TUBE					
	Glass slides		Hanging drops		Agar medium	
	Per cent	Length, μ	Per cent	Length, μ	Per cent	Length, μ
Untreated	71	450–690	77	450–690	70	200–300
Super-Sulfodust	18	5–10	19	5–10	60	70–200
Koppers dry 2–100	41	5–70	42	5–70	50	70–140
Bordeaux 1–3–100	0	0	0	0	0	0

* Koppers dry = Koppers dry wettable flotation sulfur.

The results were the same whether the slides were flat or inverted (hanging drop). The hanging drop insured a maximum oxygen relationship and intimate contact of sulfur particle and pollen grain. The same general trend was shown whether the dust was mixed with the pollen in the sugar solution or dusted on after the drops of the pollen suspension were *in situ,* and the sprays showed the same effectiveness whether mixed in the sugar solution with the pollen or sprayed on the slide, allowed to dry, and the drops of pollen suspension placed on afterward.

The toxicity tests on the agar were not so consistent, except with bordeaux. The Koppers dry wettable appeared at times to be considerably less toxic than the Super-Sulfodust. The variation in results with the dust is probably explained by the variation in the number of sulfur particles in actual contact with the pollen grains. The percentage pollen germination in tests with Koppers dry wettable was consistently more than half that of the check and the germ tubes were about half the length of those of the check.

The untreated pollen germ tubes did not seem to be so vigorous on the agar media as in the liquid media. The reverse was true of the treated pollen germ tubes. The explanation of the behavior of the untreated pollen can be attributed to impurities in the agar or to the type of agar. The fact that treated pollen grains produced germ tubes of considerable length on agar may be due to the effect of their

contact with a surface or the absorption of toxic materials by the agar. Whether or not the pollen grains *in situ* on the stigma could germinate and penetrate in the presence of flotation sulfur is a question.

The drops of treated pollen on the slides or the agar in the above tests were highly diluted with the 10 per cent cane sugar solution after the records were taken and no further growth developed at the end of 24 hours, whether there was free sulfur present or not. The sulfur particles, particularly with the finer flotation sulfur, tended to adhere to the pollen germ tubes. With the same treatment the untreated pollen germ tubes grew profusely (about 2,650 μ).

FIELD EXPERIMENTS AND RESULTS

The data obtained relative to set of fruit from dusting and spraying experiments during the blossoming periods in 1933 and 1934 are presented in Table 10. Fungicides were applied on additional series to Red Delicious and Rome Beauty each day following those for which the data are presented until the end of bloom. These data are not given, however, as there were no significant differences. Only one application was made to the trees in any given series.

The Red Delicious began to bloom three days before they were sprayed, were in full bloom when sprayed, and had had about two afternoons of bee activity, but pollen from other varieties was available for cross pollination only one day before spraying. The Rome Beauty and Wealthy blossoms were not all open May 15 and 13, respectively, when the first series (2 and 4) was applied; but they were all open when the second series (3 and 5) was applied. The Rhode Island Greening trees had 80 to 95 per cent of the blossoms open when sprayed.

While the season of 1933 was unusually ideal for experimental work, the season of 1934 was the reverse and one in which the trees had reduced vigor due to low temperatures of the previous winter. The fruit set was seriously reduced on unsprayed trees. In addition to the data presented here, practically all the experimental blocks were sprayed during bloom. None of the materials used in scab control, sulfur or copper, gave any apparent reduction in fruit set. The data are not given because a scarcity of bees, irregular or spasmodic bee activity due to poor weather conditions and the uneven set of fruit from tree to tree necessitated checks on the sprayed trees.

TABLE 10.— THE EFFECT OF THE APPLICATION OF CERTAIN SPRAY MATERIALS DURING FULL BLOOM TO THE SET OF FRUIT IN THE HUDSON VALLEY, 1933 AND 1934.

TREATMENT*	NO. OF TREES TREATED	NO. OF SPURS COUNTED	AV. NO. FRUITS PER SPUR	PER CENT SPURS WITH FRUIT
Red Delicious (J. Warner), Bloom Period May 12–19, Ser. 1, Applied May 15 (8–12 a.m.)†				
Untreated	9	1,446	0.9	61.8
Kolodust	5	1,404	0.8	61.1
Koppers dry 5–100	4	1,004	0.8	63.7
Bordeaux 2–6–100	5	1,265	0.5	45.7
Rome Beauty (J. Warner), Bloom Period May 13–22, Ser. 2, Applied May 15 (8–12 a.m.)†				
Untreated	7	664	2.4	96.5
Kolodust	5	967	1.9	96.1
Koppers dry 5–100	5	884	2.1	95.1
Bordeaux 2–6–100	5	1,033	1.9	88.3
Ser. 3, Applied May 16 (6–8 a.m.)				
Untreated	7	664	2.4	96.5
Kolodust	5	893	1.9	93.8
Koppers dry 5–100	5	560	2.3	93.2
Bordeaux 2–6–100	5	867	2.2	94.2
Wealthy (G. Sleight), Bloom Period May 12–19, Ser. 4, Applied May 13 (10 a.m.)‡				
Untreated	1	772	1.1	82.0
Koppers dry 5–100	1	780	0.9	73.6
Ser. 5, Applied May 15 (9 a.m.)				
Untreated	1	735	1.2	90.1
Koppers dry 5–100	1	989	1.1	79.5
R. I. Greening (Miss E. Shaw), Bloom Period May 6–18 Ser. 6, Applied May 10 (10 a.m.–1:30 p.m.)§				
Untreated	2	1,710	0.3	44.2
Bordeaux 2–6–100	2	1,762	0.3	46.2
Untreated	3	1,003	0.3	40.9
Coposil 3–100	3	1,985	0.4	58.0

* Koppers dry = Koppers flotation dry wettable sulfur. The data were taken after the June drop. The blossom period in general was ideal for pollination. The temperatures for each day at 10 a.m., 2 p.m., and 6 p.m., were as follows: May 11: 62°, 64°, 60°; May 12: 62°, 70°, 74°; May 13: 62°, 74°, 72°; May 14: 64°, 66°, 66°, May 15: 72°, 76°, 68°; May 16: 58°, 64°, 50°; May 17: 64°, 72°, 60°; May 18: 72°, 80°, 66°; and May 19: 80°, 80°, 68°. May 12, 15 and 17–19 were clear; May 13 and 14 were partly cloudy; and May 16, cloudy.

† The Red Delicious and Rome Beauty were about 11 years old and interplanted. The center flower of the blossom spur on the Rome Beauty began opening May 13. The Red Delicious opened one day earlier than the Rome Beauty, but it is doubtful if a pollinizer was available. Red Delicious was in full bloom May 15 and about 30 per cent of the petals were off the following day. Rome Beauty was in full bloom May 16 when sprayed and began dropping petals May 18.

‡ About 80 per cent of the blossoms were open on the Wealthy when sprayed May 13. The Wealthy were in full bloom May 15 when sprayed. The untreated and treated blooms were on the same trees.

§ Buds began to open May 6, about 50 per cent were open May 7, and petals began to drop May 12. In general 80–95 per cent of the blossoms were open when sprayed. Scarcity of bees made for little pollination. There was bee activity May 6, 9, 11, and 14. Altho cool May 8, 10, 12, and 13, there was some wild bee activity. The untreated and treated blooms were on the same trees.

The data presented indicate that the allowance of one day (at the most two) of favorable pollinating conditions with these varieties was sufficient to obtain a good fruit set; but in the final analysis due consideration must be given the fact that certain of these varieties may be self-fertile under some conditions, and consequently may set themselves when they bloom regardless of bee activity. These data are not presented as conclusive evidence but as indicative of what would have occurred with such practices for these particular seasons. The important conclusion is that, regardless of the finer technical points of toxicity, the practice of spraying during bloom for apple scab appears feasible from a commercial point of view.

While it is evident that sulfur and copper fungicides are toxic to pollen, it is possible that there may be a sufficient number of pollen grains on the stigmas which are not in contact with the toxic materials to accomplish fertilization. Due to surface tension, the danger of getting spray materials on the stigma is considerably less with a spray (unless a spreader is used) than with dust. As mentioned earlier, blossom buds open irregularly, some are sure to be fertilized before spraying, while others will not open until after spraying and will then be pollinated and fertilized.

The safer practice would no doubt be to avoid copper sprays unless fire blight is a problem.

SUMMARY AND CONCLUSIONS

Seasonal development records of apple scab (*Venturia inaequalis*) for the past five years in the Hudson Valley indicate that ascospores may be discharged over a period extending at least from the middle of April to the last week in June. The frequency and duration of the wetting periods in the early part of the season and temperature in the latter part of the season are the major factors in determining the length of time that there is danger from primary infection. Preblossom and postblossom sprays may be equally valuable. In all years, the month of May has covered the major portion of the severe primary infection periods. Commercially, the pink, calyx, 10-day, and codling moth (mid-June) sprays are the most important. The value of a given individual spray has depended on the incidence of scab the previous year and the frequency and duration of wetting periods for the current year.

Successful spraying is based on three considerations, *viz.*, correct timing or frequency of application, thoroness of application, and the

use of proper materials. For the average year spray materials for the control of scab can be classified generally into two groups, *viz.,* those that are both protective and eradicative, such as lime-sulfur and, to a lesser degree, dry lime-sulfur; and those that are merely protective, such as wettable sulfurs, sulfur dusts, and copper sprays. The selection between these two groups for any given spray, apart from injury and finish of fruit, is determined by the proximity to the primary infection periods. The value of a given individual spray is affected by the relationship of the infection period and the stage of host development to its date of application. Wettable sulfurs and the like must be applied more frequently than materials such as liquid lime-sulfur. The most advantageous program for a given orchard cannot be carried out without the division of the orchard into some such classification as (1) varieties and location or general set-up conducive to scab; (2) varieties susceptible to scab but air drainage and orchard practices good, particularly pruning; and (3) varieties not susceptible to scab but susceptible to spray injury.

Liquid lime-sulfur 1-60, thoroly applied, has given good scab control under Hudson Valley conditions. Arsenate of lead materially increases the effectiveness of lime-sulfur when applied after infection periods. Other insecticides, such as calcium arsenate, magnesium arsenate, and cryolite did not seem to affect materially the toxicity of the lime-sulfur. Dry lime-sulfur appears to be the best of the substitutes for liquid lime-sulfur that were tested. *When timely applied,* the use of wettable sulfurs, particularly in the cover sprays or after petal fall, has proved to be a desirable modification of the lime-sulfur program. Dry mix, Koppers flotation sulfur paste, Koppers flotation dry wettable, Magnetic-Spray, Sulfrox, and Kolofog, at the dilutions used in these investigations, have given, for all practical purposes, equally as effective control as the lime-sulfur sprays. Ansul colloidal sulfur paste, Camden flotation sulfur paste, and Cal-Mo-Sul were also tested but field trials have not been extensive. Data show that *untimely applications* of wettable sulfurs may result in considerable scab. Lime should not be used at a higher concentration than necessary as it may decrease the adhesiveness of wettable sulfurs sufficiently to lower their effectiveness. Indications are that lime 3-100 appears to be sufficient with wettable sulfurs embodying only elemental sulfur or liquid lime-sulfur if arsenate of lead 3-100 is also used.

Liquid lime-sulfur has not been found satisfactory for use with calcium arsenate except perhaps on hardy varieties such as McIntosh and then only to vigorous trees. A number of correctives, such as lime, iron sulfate, aluminum sulfate, and Cal-Mo-Sul, have been used with lime-sulfur with varying success. Dry lime-sulfur with calcium arsenate is apparently satisfactory on McIntosh. Of the wettable sulfurs tested, dry mix, Magnetic-Spray, and Koppers flotation sulfur proved the most satisfactory to use with calcium arsenate. Lime at the rate of 3 pounds for each pound of calcium arsenate must be used or defoliation and fruit drop may occur, even on McIntosh. Serious injury is usually associated with low vigor of trees and certain set-ups of climatic conditions such as rain or high humidity, and high temperature. It abounds where leaf cuticle has been ruptured in any way whether by gun injury, fungous lesions, insect wounds, or wind whipping. Sulfur dusts may be used satisfactorily in good orchard practice for scab control, but they are still considered in the main as a supplementary or emergency measure. While it is apparent that the fineness or lightness of the sulfur determines largely the degree of adhesiveness and the amount applied, it has been observed that such dusts as contain bentonite have given indication of value for application during a drizzly type of rain or where the foliage has not had time to dry.

Coposil, one of the most satisfactory substitutes for bordeaux mixture, appeared to give commercial control of scab. Hydrated lime about 6-100 should always be used with Coposil. Copper phosphate (with lime and bentonite) has given indication of being as good or better than Coposil in more limited trials. While there is considerable varietal difference as to when the first application can be safely made after bloom, in general it is safe to say that with the possible exception of McIntosh, the most promising copper sprays should not be applied until at least a month after petal fall. Adhesive studies show that the substitutes for bordeaux are inferior as to sticking properties and that this may be a serious drawback in scab control. Cal-Mo-Sul reduced bordeaux injury but in no way did the combination compare with Coposil.

Adhesive studies were conducted to determine in a measure the nature of the effectiveness and the amount and duration of protection afforded by the several sulfur fungicides as used commercially. The materials tested included liquid lime-sulfur, dry lime-sulfur, dry mix,

Kolofog, Ansul colloidal sulfur paste, Koppers flotation dry wettable sulfur, Koppers flotation sulfur paste, Magnetic-Spray, blended Koppers sulfur dust, Magnetic-Sulfur dust, Super-Sulfodust, and Kolodust. In general, liquid lime-sulfur was taken as the standard since it was known to give scab control.

Lime-sulfur 1-40, 1-60, and 1-80 tended to adhere to McIntosh foliage in proportion to the dilution and the three concentrations weathered off at approximately the same rate. Dry lime-sulfur 3-5-50 appears to give a protection somewhere between the liquid lime-sulfur 1-60 and 1-80. The results with dry mix at the concentrations of 16-8-½, 12-8-½, and 8-8-½ were not unlike those for the liquid lime-sulfur. Since 2 to 3 inches of rain are about the maximum to be expected between sprays and since there will be unprotected host parts due to new growth, the value of the higher concentrations is questionable, at least during the growing season. Further adhesive studies indicate that wettable sulfurs and sulfur dusts may give less than, as much as, or more protection than lime-sulfur depending principally on the rate of application and the concentration of the material used. The percentages of fine sulfur in any wettable sulfur are obviously the major point of consideration in determining its effectiveness or the concentration at which it should be used. After the excess and coarse sulfur particles have been removed by the initial rain, the materials tended to rank in adhesiveness according to the amount of fine sulfur they contained. After the first rain, the *rate* of loss is not widely variant for the several materials. Much depends, of course, on the duration of the initial rain and the amount of fine sulfur in the material. Generally a point is reached after 2 to 3 inches of rain when further precipitation has but a very slow additional action. By this time the materials were frequently on an equal sulfur residue basis.

Sulfur dusts when applied to practically dry foliage and set by dew may be reduced to a common level which is about half that of a dry wettable spray with as little as 0.14 inch of rain. The sulfur residue on the fruit is reduced to a minimum. There is apparently a considerable difference in the total sulfur residue on foliage and fruit of a given variety. As varietal differences give rise to variation in leaf and fruit characteristics, so may the residue analyses vary. There is no doubt considerable variation in sulfur distribution on leaves by the different wettable sulfurs as well as compared to lime-sulfur.

Two to three times as much washing is required to remove the equivalent arsenical residue from a variety with a somewhat rough non-waxy skin like Baldwin as compared to the smooth waxy skins of the McIntosh. Forty per cent or more of the reduction in the amount of sulfur or arsenic per unit area of fruit in mid-season may be due to redistribution of the materials by growth. Lime-sulfur and arsenate of lead are very resistant to rain and weathering. Applications made to Baldwin fruit June 29 were not reduced below the tolerance on September 28 by 19 inches of rain from 26 rains. An application of lime-sulfur and calcium arsenate was at an equivalent point with about 6 inches of rain from 12 rains. Indications are that the arsenical residue from the use of lime-sulfur with calcium arsenate is about the same or less than from wettable sulfurs with calcium arsenate. There may be considerable variation in the arsenical residue from the use of the different wettable sulfurs, particularly with the first rains, but the biological significance is open to conjecture. The wettable sulfur that leaves the least sulfur on the fruit may give the greatest arsenical residue, and vice versa, at least at a certain stage of weathering. A shower of 0.14 inch has been enough to reduce the arsenical residue of a dust block below tolerance.

Laboratory tests show that sulfur is toxic to apple pollen. Field experiments indicate that, as far as these set-ups were concerned, an allowance of one day (at the most two) of favorable pollinating conditions was sufficient to obtain a good fruit set. Regardless of the finer technical points of toxicity, the practice of spraying during bloom for apple scab control appears feasible from a commercial point of view.